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By

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A Survey of Research Done by Department Scientists

This is an effort to prepare a comprehensive exposition of the outstanding research accomplishments of the scientists of the Department of Agriculture in all branches, except the social sciences, throughout its history. It is rather surprising that a research institution so large and so well known has never before been the subject of such a discussion on a comprehensive scale. The various sections of this report have been cleared through the Agricultural Research Administration and its constituent agencies; also through the Forest Service and the Soil Conservation Service. They represent an effort of the scientific staff of these agencies to evaluate the work in the different fields. It proved difficult if not impossible to organize the material on a bureau or an administrative basis, consequently a purely functional pattern was adopted; for instance, all work on soils was placed together, regardless of the organizational unit in which it was carried on. Three of the chapters were prepared wholly or principally by individuals in the agencies most concerned: Home Economics by Helen W. Atwater, the daughter of W. O. Atwater, the nutrition scientist; Forest Service by Clark F. Hunn; and the section on publications by M. C. Merrill, chief of the Division of Publications. All other sections were prepared in the Office of Information from material submitted by the bureaus and afterwards cleared by their information offices for accuracy and balance. The account still has obvious imperfections and can be improved, especially if those who have definite information on the points covered will write in suggestions and corrections. But it offers ample evidence that Department research work has paid for itself many times over.

OCT 1 1943

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A SURVEY OF RESEARCH DONE BY DEPARTMENT SCIENTISTS

SECTION I

ORIGIN AND DEVELOPMENT OF DEPARTMENT RESEARCH

The United States Department of Agriculture originated in the Patent Office which was then in the Department of State. The first authorization for the expenditure of Federal funds for agricultural purposes was made in 1839. Until that time agriculture, in this country at least, struggled along without the aid of organized scientific research.

The first Commissioner of Patents under the new patent law of 1836 was Henry L. Ellsworth, son of the third Chief Justice of the Supreme Court, a graduate of Yale University, who was a member of the Constitutional Convention and had long had a deep interest in agriculture. He quickly noticed that farm labor-saving devices were being invented rapidly; and he urged that some regular system be established for the "selection and distribution of grain and seeds of the choicest varieties for agricultural purposes." He it was who first began to carry on governmental agricultural investigations under Congressional authority.

Before that he had, at his own expense and without official authorization, distributed many plants and seeds to farmers. Later the function of seed distribution was regularized under Congressional authority. For a long time it consumed most of the funds allocated for agricultural purposes and most of the energy of the small staff serving agriculture in the Patent Office and in the early Department of Agriculture. Seed distribution did not end until June 30, 1923. Its

long continuance in part accounts for the paucity of fundamental scientific investigation in the Department's early history.

The Department of Agriculture was created with bureau status in 1862, and its first commissioner, Isaac Newton, was a great believer in science. In his initial report, covering the last half of 1862, he said that farmers could no longer afford to destroy the soil with bad cropping methods and then move on, but must learn to make two blades of grass grow where one grew before. He defined science as the "what and how to do . . . the concentrated experience of the ages . . . classified knowledge illustrated in practice and confirmed by experience, and as certain and eternal as truth itself."

According to Newton, applied chemistry stood first among the sciences that might aid agriculture. For it would reveal the nature and composition of our soils, the kind, use, and value of manures or fertilizers, and the principles of nutrition. He quoted Sir Humphry Davy, who said: "Nothing is impossible to labor aided by science."

In this report Isaac Newton stated that some of the immediate objectives of his new department would be to experiment with agricultural implements, seeds, soils, manures, and animals; to make chemical investigations of soils, grains, vegetables, and manures; and to promote the study of botany and entomology.

Soon after the Department head was raised to Cabinet rank in 1889; Secretary Jeremiah M. Rusk, in his initial annual report wrote: "The great nations of Europe strain every effort to make science the handmaid of war; let it be the glory of the great American people to make

science the hand-maid of agriculture." But even while agricultural work was carried on in the Patent Office, before 1862, great things were expected of scientific investigation.

In 1856 the Commissioner of Patents engaged the service of a botanist at the suggestion of Joseph Henry, Secretary of the Smithsonian Institution, who also contributed articles on meteorology to the agricultural reports as early as 1857. In 1862 Commissioner of Agriculture Newton appointed a chemist, Charles M. Wetherill, and a statistician, Lewis Bollman. William Saunders, an expert gardener, became a sort of combined botanist and superintendent of the propagating garden, then on the Department grounds, and an entomologist, Townend Glover, was retained in the service.

That is how scientific investigation began in the Department. The first research publication was a six-page leaflet by Wetherill, a "Report on the Chemical Analysis of Grapes." But Newton felt that the farmer should have the aid of all the sciences and he named them: Meteorology, electricity, botany, hydraulics, vegetable physiology, geology, anatomy, animal physiology, animal pathology, and plant pathology.

Growth of the Scientific Staff and Organization

At the end of Newton's term of office in 1867, the Department's scientific staff consisted of a statistician, an entomologist, a chemist and an assistant chemist, a superintendent of the experimental garden and his assistant, and a botanist. These scientists carried on the

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more obvious kind of investigations, naturally doing little that today would be regarded as fundamental research. The chemist was perhaps most favored and much was expected of the science of chemistry.

In the 1870's a "man of approved attainments" to conduct inquiries into timber supplies and a veterinarian were appointed. In the 1880's came ornithologists, mammalogists, dairy specialists, and a special road engineer. Studies of human nutrition and organized investigation of soils began in 1894, of irrigation in 1898, and of land drainage in 1902. Such, in brief, was the development of scientific investigation in the early Department of Agriculture.

In 1883 the Department's scientific agencies consisted of Divisions of Gardens and Grounds, Botany, Microscopy, Chemistry, Entomology, Statistics, Veterinary Medicine, and Forestry. By 1889, it had Divisions or Sections of Statistics, Entomology, Chemistry, Silk Culture, Botany, Vegetable Pathology, Economic Ornithology, and Mammalogy, Microscopy, Forestry, Gardens, Grounds, and Horticulture, Pomology, the Office of Experiment Stations, and the Bureau of Animal Industry, which had been established by Congress to combat animal diseases, in 1884, as a result of public pressure. The Weather Bureau became part of the Department in 1891.

Creation of Other Bureaus

On July 2, 1862, about 6 weeks after he had signed the act creating the Department of Agriculture, President Lincoln approved the Land-Grant College Act, fathered by Justin Smith Morrill of Vermont. This act

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endowed the State Colleges with 11 million acres of public land which they were authorized to sell, using the proceeds to finance and operate themselves. On March 2, 1887, the Hatch Act was passed establishing the first national system of agricultural experiment stations in the world.

The Office of Experiment Stations, W. O. Atwater, Chief, and A. C. True, his associate, was established to administer the provisions of this law. The Department was to act in a supervisory capacity, to furnish forms for the tabulation of experimental results, to indicate fruitful lines of inquiry and keep track of finances and of research projects, and to give expert advice and assistance as required by the stations. Federal aid to State experiment stations thus became a reality. The stations were directly under the supervision of the land-grant colleges in the respective States.

In 1898, when James Wilson was Secretary of Agriculture, the Department's scientific agencies were: Bureau of Animal Industry, Office of Experiment Stations, Weather Bureau, Division of Gardens and Grounds, Division of Chemistry, Division of Entomology, Division of Statistics, Division of Botany, Division of Forestry, Biological Survey, Division of Pomology, Division of Vegetable Physiology and Pathology, Office of Fiber Investigations, Office of Road Inquiry, Division of Agrostology, Division of Soils.

The Bureaus of Chemistry, Soils, Forestry, and Plant Industry were established as separate agencies in 1901. With the Weather Bureau and the Bureau of Animal Industry they comprised the principal scientific

units of the Department at that time. The Division of Entomology became the Bureau of Entomology in 1904 and the Division of Biological Survey the Bureau of Biological Survey in 1904. The Bureau of Public Roads was created in 1918, the Bureau of Home Economics in 1923; and the Bureau of Dairying (now Dairy Industry) in 1924. The Bureau of Agricultural Engineering was made a separate agency in 1931.

Meanwhile, in 1927, regulatory work was separated from research in the Bureau of Chemistry. The former became the Food and Drug Administration, and the latter was combined with the Bureau of Soils to become the Bureau of Chemistry and Soils. In 1927 also the Federal Horticultural Board became a separate administrative unit known as the Plant Quarantine and Control Administration; in 1934 it was combined with the Bureau of Entomology to form the Bureau of Entomology and Plant Quarantine. In 1938 the work of the Bureau of Agricultural Engineering was combined with parts of that of the Bureau of Chemistry and Soils and the unit was designated the Bureau of Agricultural Chemistry and Engineering.

In 1939, the Bureau of Public Roads was transferred from the Department to the Federal Works Agency. In 1940 the Food and Drug Administration was transferred to the Federal Security Agency, the Weather Bureau to the Department of Commerce, and the Biological Survey became part of the Fish and Wildlife Service in the Department of the Interior.

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is not said in derogation of the Department's early scientific workers. It is a mere indication of the relative stage of progress that scientific research itself had then attained.

It was only in 1840 that Justus von Liebig's influential work, Chemistry in its Application to Agriculture and Physiology, appeared, which gave stimulus to the application of science to farming. Of course, there was the earlier publication of Sir Humphry Davy's Elements of Agricultural Chemistry in 1813, but even Liebig's book would now be regarded as primitive.

Between 1836 and 1850 subjects which largely engaged the attention of pre-Department scientists were such as: Variety improvement to increase the yields of economically valuable plants; accurate crop statistics; the use of agricultural labor-saving machinery; the extraction of sugar from beets, and from corn stalks; the culture and manufacture of silk; the production of domestic flaxseed; soil and fertilizer analyses; the general application of chemistry to agriculture; improved culture of crop plants; new modes of fencing and of building farmhouses; destructive potato diseases; depredations of the hessian fly and other insects which menaced wheat; the effect of soil, climate, and shipping on the quality of wheat grain and flour; sugarcane growing; the preservation of foodstuffs; the improvement of domestic animals; the preservation and enhancement of soil fertility.

Between 1851 and 1862 the following might be cited: Methods of deodorizing and concentrating nightsoil for fertilizer, introduction of soybeans (1853), importation of camels, weather investigation,

plant adaptation (1856); tea culture; the use of steam plows and cultivators; bee culture; fish propagation; grape culture; forests and trees; contagious pleuropneumonia of cattle; reclamation of the soil; dairy farming.

The following subjects were frequently discussed in the early agricultural reports: Domestic animals, insects, fertilizers, bread crops, textile and forage crops, tobacco, sugar cane, sorghum, broomcorn, tomatoes, capers, okra, fruits, nuts, wine, gardening, hedges, climatology.

Between 1862 and 1870 these additional subjects were emphasized: making two blades of grass grow where one grew before; the increased application of chemistry to agriculture; cotton culture; flax, hemp, alpaca, opium poppy, hops, and birds; feed for livestock and farm animals; culture of oranges and citrons; analyses of mineral waters, foods, and certain pharmaceutical preparations.

Early investigation therefore consisted in comparatively simple experimentation with plants, soils, and fertilizers, accompanied by chemical analyses insofar as possible, plus the compilation of statistics, the writing of half-speculative articles, and the studies of the botanists. Seed distribution overshadowed all. Scientific methods were crude but so little was known that almost anything undertaken yielded some modicum of new knowledge.

This should not be taken to imply that nothing of value was done. The Department was small and so were its appropriations. Its staff was very limited. Despite the fact that chemistry early engaged the attention of the Department's commissioners, Secretary Rusk, when he took office in 1889, found the "chemical laboratory crowded into a

damp, ill ventilated, and wholly unsuitable basement, originally intended no doubt for storage purposes." Its work was restricted, its equipment poor, its staff underpaid and overworked. Rusk also found entire scientific divisions crowded together in small rooms to an extent that prevented them from properly exercising their functions.

In another field, Townend Glover, the entomologist, did excellent work which gained considerable recognition abroad. William Saunders, the superintendent of gardens, and statistician J. R. Dodge were both distinguished men well qualified for the duties they ably performed. Chemist William McMurtrie initiated the classic work on finding the best localities in the United States for sugar-beet growing, later brought to fruition by Harvey W. Wiley, who became chemist in 1883. Peter Collier, who was chemist after McMurtrie, probably did more than anyone else to introduce sorghum into the United States. Dr. D. E. Salmon, in charge of the Veterinary Division before the Bureau of Animal Industry was created, and then chief of that Bureau, was also a distinguished scientist.

Many of the subjects that engaged the attention of Department scientists in the early days of its existence still require study. Of course some of the investigations ran up dark alleys or wound up in dead-end streets. Because scientific methods developed slowly, many subjects required study for a long time. As agriculture progressed some problems no longer remained problems.

On the other hand actual solutions were found for many problems and results of great monetary benefit accrued to the general public. In other

cases basic scientific discoveries were made which for years thereafter yielded an unearned increment of added value in widespread fields. As is common in scientific investigation some problems were solved only to give rise to new dilemmas which in turn demanded solution.

Silk Culture

It may be useful to trace briefly the history of three matters often mentioned in early Department reports: silk culture, making sugar from cornstalks, and the ravages of the hessian fly.

Early in Department history agricultural scientists often sought profit for American farmers in what were later regarded as exotic projects, such as the importation of camels, sponsored by the War Department, the domestic cultivation of the opium poppy, the breeding of Merino sheep, and the culture of silk. On May 11, 1826, the House of Representatives passed a resolution calling on the Secretary of the Treasury to furnish information on the growth and manufacture of silk. This led to an extensive inquiry on the subject and the preparation of a manual of 220 pages under the direction of Benjamin Rush, Secretary of the Treasury. The House issued the result as a document in 1828. Thus Congress itself published the first agricultural bulletin.

Count von Hazzi of Munich, having seen a copy of the House resolution regarding silk culture, then transmitted to Congress, through James Mease, "A Treatise on the Rearing of Silk Worms." This the House also issued as a document in 1828. These publications reflected a great deal of private effort devoted to silkworm culture.

In 1865, Townend Glover carefully brought back some silkworms from an entomological convention he had attended in Paris. In 1884 Congress made an appropriation of $15,000 for the promotion of silk culture; with that silkworms and mulberry trees were distributed. The work continued for some time, the main effort being to reduce the cost of silk production to the point where a domestic commercial industry could be established in competition with the cheap-labor industry in foreign parts. The main problem was to find a machine that could be used to reel silk from cocoons.

This stage of the work terminated in 1891, because efforts to find a machine that could be used economically for reeling silk from cocoons proved unsuccessful. Many years later, as Japan began to prove troublesome and silk imports were menaced, new interest was aroused in the subject. On August 19, 1941, the chief of the Bureau of Entomology and Plant Quarantine issued a mimeographed letter to answer numerous inquiries regarding silk culture. According to this, appropriations for silk work were continued until 1908, since which time the Department has had neither funds nor authorization to carry it on.

But after discontinuation in 1891, investigation was undertaken again in 1902. It was shown that, with reasonable care, silkworm cocoons could be produced almost anywhere in the United States. Mulberry trees also did well throughout the country. But the costs of raising the cocoons and reeling raw silk were prohibitive. Bulletins and reports hitherto issued on the subject were then out of print. No published information was available. Distribution of silkworm eggs and

mulberry cuttings had been discontinued years before. The investigation had proved productive scientifically though the results could not be applied practically for economic reasons.

Sugar from Cornstalks

In his reports as patent commissioner, Henry L. Ellsworth, who served from July 4, 1836 to May 4, 1845, and who first undertook seed distribution and the compilation and publication of agricultural statistics in the Patent Office, mentioned the new method of making sugar from cornstalks. In his report for 1841, dated January 1842, Ellsworth said that the saccharine content of cornstalks could be trebled by removing the ears before they were well formed, and that experiments in Delaware had shown 1,000 pounds of sugar per acre of corn could be produced.

He returned to this subject in his last annual report, dated January 6, 1845, wherein he confuted those scientists who had held cornstalk sugar to be grape sugar. Ellsworth said instead that it was "equal to the best muscovado sugar." He felt sure that it would soon be produced from cornstalks on large scale. It never was. It was in this same report that he mentioned the destruction of wheat by hessian flies. What about these two projects?

A little before 1840 the French botanist Pallas announced that, if undeveloped ears of corn were removed before maturing, the stalk sugar content increased. This discovery was expected to have great economic importance. Great Britain had abolished slavery in 1836, its colonial

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cane sugar production declined, and the world seemed to face a sugar famine. Naturally Americans felt the United States should learn to produce its own sugar. So the Patent Office began to investigate the matter and soon reported success.

But in 1850 "Chinese sugarcane" or sorgho, was introduced in France, in 1854 the Patent Office got seeds of it from Paris, and the sorghum project submerged the cornstalk-sugar project. Plots of sorgho cane were grown in Washington and the seeds were sent all over the country. Samples of the cane and its juice were analyzed by well-known chemists. In 1856, for instance, C. T. Jackson of Boston, one discoverer of ether's anesthetic properties, made a report on sorgho to the Patent Office, and in 1858 a hundred thousand acres of sorgho were planted. Some of the earliest work of the Department's first chemists was on this plant, - Antisell, McMurtrie, Collier, and Wiley, for instance.

Collier, in 1881, also conducted the Department's first extensive work on sugar from cornstalks. This sugar was exhibited at the St. Louis Exposition in 1903. But the low purity of cornstalk juice became the main obstacle to production.

Wiley took over Collier's work and had 60 acres of sorghum planted near Eckington, now in Washington, D. C. This was probably the greatest crop of sugar-producing plants ever raised in the District of Columbia. But soon after, Wiley turned to sugarcane and sugar beets, and did such notable work that he was largely instrumental in establishing these industries in the United States. This is the same Wiley who was known later for his successful agitation to have the first Food and Drug law passed.

Then, as late as 1912, the Department began again to carry on experiments on cornstalk sugar. Crystalline sugar was obtained, but the process did not appear to be feasible commercially. The outstanding patent for the treatment of maize in this process was taken out by F. L. Stewart in 1906. The Department's experiments showed an average of 12 percent sugar in cornstalks.

The process of making sugar from them resembles that used in making sorghum sugar. Cornstalk sirup has been made also and is of satisfactory quality for cooking. The final Department publication was entitled "Preliminary Report on Sugar Production from Maize", and was by C. F. Clerk, an agronomist in the Bureau of Plant Industry, the work having been carried out under direction of the well-known scientist, W. A. Orton. Again a scientifically productive project proved infeasible commercially.

The Hessian Fly

We come finally to the destructive hessian fly, the ravages of which worried Commissioner Ellsworth. In 1889, Francis M. Webster of the Ohio Agricultural Experiment Station discovered that the hessian fly emerges in the fall, and deposits its eggs during a progressive wave of emergence beginning in southern Minnesota about September 12 and traveling southward to the southern border of the Winter Wheat Belt, where it arrives around October 27. With due allowance for these facts it appeared that safe planting dates could be selected so that the wheat would escape the depredations of the fly. Professor Webster also served before 1904 as a field agent for the Bureau of Entomology, but in 1904 he came to Washington to organize the Bureau's Division of Cereal and Forage Insect Investigations.

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Andrew D. Hopkins, at the time State entomologist for West Virginia, discovered that the hessian fly's emergence date varied directly with the altitude. He then prepared a planting schedule based upon latitude and altitude; this was published in 1900, and therein he gave Webster credit for the original discovery mentioned above. Dr. Hopkins continued his studies until his death in 1916. Farmer's Bulletin 1627 recounts his work. A map therein shows safe sowing dates for various parts of the country and it has had to have only minor adjustments since. When the hessian fly is abundant, wheat growers generally plant on the recommended dates, and their crop thus escapes damage.

Field laboratories of the Bureau of Entomology and Plant Quarantine now conduct regional surveys to determine hessian fly abundance, density of infestation, and the extent of parasitism present. The results are reported to State agricultural authorities who issue warnings based upon them. Before this plan was adopted in 1917, disastrous outbreaks of the fly did tremendous damage at rather regular intervals of from 6 to 7 years. No such outbreak has now occurred for 25 years. That is how the hessian fly problem was solved.

Scientific Specialties and Specialists

Originally Department research organization was very simple. Science itself was simple in those days. The Commissioner appointed a botanist, a chemist, a statistician, an entomologist, and scientific investigation got under way. For many years thereafter there was included in the book containing the annual report of the head of the Department a report from the Chemist, the Botanist, the Entomologist, the Statistician, the

Microscopist, and so on.

Later science itself became more complex. The specialties split off from the major sciences. Department scientific work had to be reorganized and incipient agencies were set up, usually sections or divisions, sometimes offices. Furthermore it was found that one science might prove useful in several different lines of work. That early proved true of statistics and microscopy, later of chemistry and bacteriology.

Thus in the Department's annual report for 1870 a man who signed himself "Thomas Taylor, Microscopist" made a report to Commissioner of Agriculture Watts and in 1871 his report spoke of a Microscopic Division having been formed. Taylor was a remarkable man. Hired originally to study rusts, mildew, smuts, molds, and other fruit, vegetable and berry diseases with the microscope, he branched out ultimately into widely variant fields.

This was largely after 1878 when the relationship between "dairy prime butter" and oleomargarine began to interest him, as well as some Demarara sugar he was examining for the Treasury Department. Before this and for some time after, he also studied edible and non-edible mushrooms. In 1880 he reported on a sulfuric-acid treatment which he had found to quicken the germinating power of seeds.

In his report for 1881, however, he had studied not only the diseases of fruits and vegetables, but also food adulterants, with special attention to butter, oleomargarine, lard, milk, and "poisoned cheese," and he had had a look at swine trichinae. By 1884, the passage of the oleomargarine law, with heavy penalties for infraction, had led him to perfect tests for the detection of butterfat substitutes such as cottonseed oil, benne

oil, and "ground-nut" oil. He had issued a bulletin on the subject.

In 1888 Taylor turned his attention to spices and condiments. Foodstuffs more generally followed, including tea. In 1890 he was testing the tensile strength of vegetable fibers and in 1892 he reported improvement in his tests for individual butter adulterants. Already he had covered a wide field. He was a scientist of real talent and his work was useful and suggestive in the extreme.

The report of the Secretary of Agriculture for 1893 remarked, however, that Taylor's work would soon be assigned to the Division of Botany and the Division of Vegetable Pathology. But nothing was done until 1895. In that year the Secretary reported that there were now microscopists in all laboratories and that the very existence of a separate Division of Microscopy was absurd under the circumstances. The same thing had become true of statistics.

The Secretary stated that the Department of Agriculture at that time used some 500 "microscopists" or at least people who relied at times on microscopes. They were all working outside the Division of Microscopy. Hence the Division was abolished as of July 1, 1895. Its apparatus and materials on fungi went to the Division of Vegetable Pathology, that on food adulteration to the Division of Chemistry, and that on fibers to the Office of Fiber Investigation.

Thus the microscopist not only introduced the use of the microscope throughout the Department, but he may be said to have initiated at least three varied lines of work. Ultimately it became absurd to have a report from the Chemist as such because chemistry had spread throughout the Department. Finally the emphasis was placed upon the problem, the project,

or the broad lines of work, rather than upon particular branches of science. Then any kind of scientific specialist could pitch in and help where and when needed.

Organizational Changes

Many organizational changes have taken place affecting the Department's scientific agencies but most of these will be noted in the appropriate sections to follow.

A comprehensive organizational step was taken December 13, 1941, however, when all scientific research in the Department of Agriculture was placed in the Agricultural Research Administration, except that in the Forest Service and in the Soil Conservation Service. The agencies and administrative units then included in the Administration were as follows:

The Bureaus of Animal Industry, Plant Industry, Entomology and Plant Quarantine, Home Economics, Agricultural Chemistry and Engineering, and Dairy Industry; the Office of Experiment Stations; the Beltsville Research Center; the four Regional Research Laboratories; and the Bankhead-Jones Special Research Fund Laboratories.

The Bankhead-Jones Act of 1935 provided for scientific, technical, economic and other research into laws and principles underlying basic agricultural problems in their broadest aspects. It called also for research to improve the quality of agricultural products, to develop new and improved methods for their production and distribution, to discover uses for farm products and byproducts and manufacturers thereof, and to study the conservation, development, and use of land and water resources for agricultural purposes. Nine laboratories were established as a result

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Organizational Changes

Many organizational changes have taken place affecting the Department's scientific agencies but most of these will be noted in the appropriate sections to follow.

A comprehensive organizational step was taken December 13, 1941, however, when all scientific research in the Department of Agriculture was placed in the Agricultural Research Administration, except that in the Forest Service and in the Soil Conservation Service. The agencies and administrative units then included in the Administration were as follows:

The Bureaus of Animal Industry, Plant Industry, Entomology and Plant Quarantine, Home Economics, Agricultural Chemistry and Engineering, and Dairy Industry; the Office of Experiment Stations; the Beltsville Research Center; the four Regional Research Laboratories; and the Bankhead-Jones Special Research Fund Laboratories.

The Bankhead-Jones Act of 1935 provided for scientific, technical, economic and other research into laws and principles underlying basic agricultural problems in their broadest aspects. It called also for research to improve the quality of agricultural products, to develop new and improved methods for their production and distribution, to discover uses for farm products and byproducts and manufactures thereof, and to study the conservation, development, and use of land and water resources for agricultural purposes. Nine laboratories were established as a result

of this legislation.

The Agricultural Adjustment Act of 1938 provided for the establishment of four large Regional Research Laboratories for fundamental research in the utilization of farm products and byproducts. These laboratories are located at Peoria, Ill., New Orleans, La., Wyndmoore, Pa., and Albany, Calif. Their primary job is to bring chemical and engineering research into joint play to develop new uses for or to expand existing uses of agricultural products.

When the Department was reorganized in late 1942 and early 1943, as a result of the President's Executive Order placing the Secretary in charge of the Nation's wartime food program, the work of the Agricultural Research Administration was closely integrated with that of the Food Production and Food Distribution Administrations, and its functions were more fully clarified. The ARA became fully responsible for all physical, chemical, nutritional, biological, engineering, and other research, and development activities relating to food and food facilities, and the liaison agency on research problems with other units of the Department and other agencies, public and private. Its Administrator was designated Associate Director of Food Production. In February 1943, other organizational changes were made within its structure to facilitate its work. These are noted elsewhere in the appropriate sections.

SECTION II

ANIMAL INDUSTRY

In 1842 Peter Dunn, a milkman located near South Ferry, New York, bought a ship's cow from the captain of the English ship Washington. Unknown to Peter Dunn this cow had contagious pleuropneumonia, an insidious, destructive cattle disease. It carried the malady to Dunn's herd whence it spread rapidly to other herds nearby.

Owners either failed to recognize the disease or kept quiet about it. Long prevalent in other countries, it was known in the United States only by its dread reputation. Soon it raged over New Jersey and New York States and, in 1859, it was introduced into Massachusetts by four infected cows imported from the Netherlands.

Infection continued to spread to other States. By 1879 livestock men were fully aroused to the danger. So far no large nation had ever succeeded in stamping out an extensive infection. On February 6, 1879, the British Privy Council issued an order that all American cattle arriving in English ports should be slaughtered promptly at the docks. This action forced the price of American steers down $10 below that of Canadian animals. This alone meant a loss of a million dollars a year to American livestock growers, aside from losses caused by the disease among cattle in this country.

State action had failed to stamp out the disease. Some States were vigilant and cooperated loyally, but others were careless, and the

negligence of one State could upset the efforts of eradication by others. Some cattle owners kept the existence of the disease among their animals a secret and even sold affected cattle. So the industry demanded Federal action in a field in which the central Government had not hitherto intervened.

In 1884, William H. Hatch of Missouri, then chairman of the Committee on Agriculture, introduced a bill to establish a Bureau of Animal Industry in the Department of Agriculture which itself then had essentially a bureau status. This so-called "horse doctor" bill met scornful opposition. But livestock men persisted, for they knew contagious pleuropneumonia could never be controlled if it once reached the herds on the unfenced plains of the West.

A rising tide of public opinion forced passage of the bill. Since 1842, Great Britain had suffered an annual loss of $10,000,000 because of this one cattle disease. Had the disease spread in the United States for 5 more years it would have produced losses of over $1,000,000,000. Actually the campaign of eradication carried on by the Bureau of Animal Industry was a complete success within 5 years at a cost of $1,509,100. We were losing almost that much annually in exports to Britain alone.

There has been no outbreak of contagious pleuropneumonia in the United States since 1892, when Secretary of Agriculture Rusk proclaimed the country free from it. Other countries still fight this cattle disease; no large country but ours has ever extirpated it. This work of permanent eradication was itself classic. It saved the livestock industry from constant devastation, and the Nation now had the Bureau of

Animal Industry to perform many other tasks. Details of this story will be found in early annual reports of the Bureau of Animal Industry.

Story of Cattle-Tick Fever

A little before contagious pleuropneumonia was eradicated a somewhat diffident young physician joined the Bureau's staff. It was a dramatic moment that reminds us of Exodus 9:3: "Behold the hand of the Lord is upon the cattle which is in the field, upon the horses, upon the asses, upon the camels, upon the oxen, and upon the sheep; there shall be a very grievous murrain." In short, cattle-tick (once miscalled Texas) fever seemed now destined to be a curse to cattle raising in the Southern States forever. The shy young man was Theobald Smith.

Cattle-tick fever was introduced into this country in Colonial times from the West Indies and from Mexico. It caused tremendous havoc in the nineteenth century. Outbreaks occurred not only in the South but in the North as well. Observers noted that southern cattle, even if apparently in good health, left a trail of fever whenever they were driven north. Northern cattle raisers demanded Government action because again State regulations failed them.

Thus it was that, in 1884, Theobald Smith was placed in charge of animal-disease investigations in the Bureau of Animal Industry, of which the distinguished veterinary scientist, D. E. Salmon, was head. Working with him were F. L. Kilborne and Cooper Curtice.

Smith naturally assumed that the tick fever was a disease carried by bacteria. He early observed that the red blood corpuscles of animals

attacked by the disease were destroyed. He next found a peculiar micro-organism, a protozoan, in the red blood corpuscles. He did not know how it got there, but was at first reluctant to accept the tick theory of its distribution which was already espoused by some, including his colleagues.

In fact, medical doctor Smith was just a little distrustful of mere "horse doctors." But Dr. Curtice had long been studying the habits and biology of the cattle tick. By about 1890 he knew its life history. He began to accept the theory of certain cattle growers that ticks transmitted the disease because certain of his own experiments confirmed the theory. He formulated an experimental plan that might be followed in the effort to indict the tick scientifically.

Dr. Kilborne worked with both ticks and cattle. He discovered that if the cattle ticks were eradicated the fever disappeared. Until then all medication had been found useless and no effective control methods had been formulated. Now, with Curtice's and Kilborne's clues in hand, Theobald Smith planned careful experiments which showed for the first time in medical history that an insect could act as an intermediary host in the transmission of a protozoan disease.

Thus Smith connected the appearance of the causative organism with the phenomenon of its transmission by the tick. It was proved that young ticks could infect cattle by transmitting the deadly protozoan in their bite. Eradication work got under way as soon as the necessary public understanding and support were obtained. By 1941 cattle-tick fever existed in less than 1 percent of the area originally ravaged by it.

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Furthermore, the discovery that infective agents can attack animals by utilizing an intermediate host resulted in solving the transmission problem of 50 or more other diseases affecting men and animals, such as malaria, African sleeping sickness, Rocky Mountain spotted fever, yellow fever, nagana, and tularemia. When the role of the mosquito in the transmission of yellow fever became clear Americans were able to complete the Panama Canal with comparatively small loss of human life. Yellow fever, not lack of engineering ability, prevented the French from doing this.

(Bureau of Animal Industry Bulletin No. 1, on the "Nature, Causation, and Prevention of Texas Fever," by Theobald Smith and F. L. Kilborne, issued in 1893, remains a classic in the field of medical research publication.)

A sidelight on how one piece of research leads to another and both to something of considerable commercial value is the development of dips used to aid in cattle-tick eradication. After experimenting with various chemicals to discover a practical method of dipping cattle to destroy the ticks that carry tick fever and yet cause no injury to cattle, scientists in the Bureau of Animal Industry developed a satisfactory arsenical dip. At first the dip was prepared by mixing caustic soda, white arsenic, and sal soda, or boiling a mixture of sal soda, white arsenic, and pine tar.

In recent years these home-made dips have been discarded owing to the availability of many commercial dips that need only be mixed with water in the dipping vat. Vast quantities of commercial dips have been

used in the extensive campaign of tick eradication which is now more than 99 percent complete. A conservative estimate made in 1906, when the eradication work was begun, placed the annual loss caused by ticks in the United States at $40,000,000 and indicated that the ticks also lowered the assets of the South by an additional $33,000,000 annually. Besides the benefits here outlined, tick eradication brought about the use of vast quantities of cement, fencing, and other commodities used in the dipping work and later in the handling of the growing cattle industry of the South.

Finding the "Lazy Bug"

In the Eighteenth Annual Report of the Bureau, issued in 1902, there is a summary (pp. 183-219) of the work of Charles Wardell Stiles on "The Significance of the Recent American Cases of Hookworm Disease (Uncinariasis or Anchylostomiasis) in Man." Stiles was trained in Germany under the outstanding parasitologist of his day. He was appointed zoologist in the Bureau of Animal Industry in 1891 and placed in charge of the Zoological Laboratory. He carried out a wide variety of investigations on the parasites of domestic animals and became interested in the hookworm problem.

Stiles became familiar with hookworm disease as it existed in the Old World and noted among the symptoms caused by the Old World hookworm dirt-eating which, among the people in the South, he knew indicated hookworm infestation. He kept telling his students in the medical schools where he lectured to keep a lookout for the worms, but some physicians,

including William Osler, scoffed at the idea. Finally one of Stiles' students, Bailey K. Ashford, found hookworm disease in Puerto Rico. In 1901 he returned to Washington with a large collection of specimens.

The parasite causing hookworm disease in man in this country was not discovered until 1902, when Stiles found significant differences between the Old World hookworm and worms obtained from patients by Dr. Thomas A. Claytor of Washington, D. C. and Dr. Allen J. Smith of Galveston, Tex., as well as those collected by Ashford in Puerto Rico. The report of these findings was made before the American Gastroenterologic Association at its fifth annual meeting in Washington, D. C., May 1, 1902.

Soon after, Stiles was appointed professor of Zoology in the United States Public Health Service, but was retained by the Bureau as consulting zoologist. Shortly after assuming his new duties, he set out on an investigational tour of the South to study the prevalance of hookworm disease. The results of this survey were presented before the Pan-American Sanitary Conference held in Washington December 4, 1902. His discovery of the "lazy bug" was hooted and denounced; he was cartooned satirically. Organized aid for hookworm sufferers for the time became impossible.

But finally in 1908, through Theodore Roosevelt's Country Life Commission, Stiles made a survey in the South and managed to get the ear of Henry Wallace, grandfather of the present Vice-President, and of Walter Hines Page. He showed them cases of the disease on train platforms as they traveled together through the South. He said these human sufferers could be cured at 50 cents each. By 1927 more than 7,000,000 sufferers had

including William Welsey, enrolled in the Army. Finally one of Stiles'
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could be cured at 50 cents each. By 1927 more than 7,000,000 sufferers had

been treated successfully. Stiles later collaborated with the staff of the Rockefeller Institute at the Hygienic Laboratory and the sanitary and other measures he suggested went far to raise the general social and economic level of several million people. He lived until January 24, 1941.

Around 1920, Maurice C. Hall, who had previously worked in the Bureau of Animal Industry, returned from war work he had carried on in an outside pharmaceutical firm and consulted a scrawled notebook in which he had jotted down projects from which he might later work. In the notebook he observed some such entry as: "Try organic compounds to eradicate hookworm." As he had tried chloroform and found it moderately effective, he tested the closely related compound, carbon tetrachloride. It was a success.

Sometimes research works out that way, but much less often than research workers would like. Naturally Hall worked first on dogs as he was trying to solve the hookworm problem for them. Carbon tetrachloride proved effective, but would it poison human beings in the dosages required and as administered? Hall didn't know, so he took some doses himself and felt none the worse. He then tried the method on other human beings with complete success.

The remedy later proved useful in treating other animals and for eradicating other types of worms. Ultimately, from 15,000,000 to 20,000,000 human victims of hookworm received treatment. Victims of the hookworm are often totally incapacitated and, even if ambulant, their work capacity is reduced an average of 35 percent. The successful treatment of so many inadvertently shiftless and inefficient people, making many of them self-supporting, added tremendously to our national income. This is conservation

of human resources on a grand scale. Even if the very low figure of $1 each is set as the benefit derived from the treatment it means that the discovery was worth $15,000,000 to $20,000,000.

The work continued and methods were improved. Hall himself made many other important investigations. His pioneer publications appeared in the Journal of Agricultural Research in 1921 and 1923.

The Debt We Owe to One Scientist

Marion Dorset entered the Bureau of Animal Industry as an assistant chemist in 1894. A few years later he was publishing work of fundamental importance on hog cholera, though he also worked on the biochemistry of the tubercle bacillus, the keeping quality of meats, and the development and testing of dips and disinfectants. As late as April 1934, he introduced a new tuberculin since used in tuberculosis-eradication work among cattle. He also produced the effective and harmless fluid used to mark federally inspected meats.

Dr. Dorset organized the system of Federal inspection in establishments licensed by the Government to manufacture serums, viruses, toxins, and related veterinary biological products. He formulated the laboratory procedures used in the administration of the Federal Meat Inspection Act. He was active in the formation of the Federal Insecticide and Fungicide Board. Under his suggestion coworkers devised a rapid method of detecting pullorum disease in chickens, a boon to the poultry industry.

It would be almost impossible to overestimate the value of Dorset's work in monetary terms. In later years he was a small grayish man who

walked with a limp, very different in appearance from tall, distinguished-appearing Dr. Hall.

At the time the Bureau of Animal Industry was founded at least $25,000,000 to $30,000,000 worth of American hogs (at times as many as 6,000,000 animals) died annually from hog cholera. The disease appeared among hogs during the Civil War and some regarded it as human in origin. Farmers worked hard and spent hard cash to raise many hogs that never got to market. Could the disease be controlled? It was supposedly of germ origin.

In 1898 two German investigators reported an attempt to immunize cattle against dread foot-and-mouth disease. They had filtered a quantity of virulent lymph, obtained from infected animals, through a filter that would hold back bacteria. This filtrate nevertheless produced foot-and-mouth disease when injected into cattle.

That meant that there were virulent infective agents so small that they could go through the finest filters known. They could not be seen even with microscopes of the highest power. Here was something basic. Soon it was shown that such an agent, called a filtrable virus, produced contagious pleuropneumonia of cattle. As hog cholera also caused huge losses, what about it?

Dorset took up here. He soon found that hog cholera was caused not by a bacterium but by a filtrable virus. This was the first time in history that a disease previously attributed to the former had been proved to be caused by the latter, which was epoch-making. Following Dorset's discovery it was found that yellow fever, smallpox, measles, and many

other ills were caused by viruses. Many competent experts classified Dorset's work with that of Pasteur and Koch.

Dorset next perfected a serum which was highly effective in protecting hogs from cholera when properly used. This serum is now prepared in about 50 plants under a public-service patent. During the fiscal year 1942 these establishments produced 1,387,785,000 cubic centimeters of the serum. Just before his death, Dorset developed and introduced a crystal-violet vaccine for hog cholera. Under some conditions, subsequent tests showed, it has a number of advantages over the combination virus-serum treatment. The use of these remedies saves American hog growers from $10,000,000 to $ 75,000,000 annually, the sum depending upon the price of pork and other factors. For purposes of comparison the entire work of Dorset's laboratory cost about $130,000 a year, around 1933, and the entire Bureau of Animal Industry about $12,000,000.

Dorset performed and directed much other valuable work which will be mentioned later. Dr. Dorset died in the service July 14, 1935.

[Two of Dorset's primary publications were: The Etiology of Hog Cholera, M. Dorset, B. M. Bolton, C. N. McBryde, Bureau Animal Industry Bulletin 72, 1905, and, Further Experiments Concerning the Production of Immunity from Hog Cholera, Dorset, 1908.]

Research and Trichinae

B. H. Ransom's research covered another aspect of hog raising. It also concerned human beings rather directly. When Ransom began his work there was no effective method of protecting the American public from trichinosis derived from hog meat. No existing inspection method could be

depended upon. Although microscopic or other laboratory methods probably eliminated heavily infested carcasses, many lightly infested ones were overlooked, and a false sense of security was created in consumers' minds. Ransom developed effective methods for the control, during processing, of the trichinae in meats that are usually eaten uncooked. The methods were generally adopted.

They involve cooking, refrigeration, or special curing, and are carried out effectively at meat-packing establishments that operate under the close scrutiny of the Federal meat inspection service. During the calendar year 1941, it is estimated that 1,022,377,635 pounds of such products were produced under Federal inspection. If the German microscopic method of inspecting hog meat for trichinae were used it would involve the expenditure of at least $5,000,000 a year more for meat inspection in the United States, or almost double the present cost. It would also be less effectual than the Ransom preventive method.

In addition Ransom developed a swine-sanitation method, to control internal parasites, which enabled farmers to produce as many grown pigs annually from two sows as they formerly did from three. If the method is not used, many more pigs die before reaching maturity; when it is used not only do the pigs survive better, but they reach marketable size more quickly. The research thus had double value economically, and it helps prevent trichinosis in human beings as well.

(Three of Ransom's more important publications were: Effects of Heat on Trichinae, B. H. Ransom and Benjamin Schwartz, Journal of Agricultural Research, 17 201-221, 1919; Effects of Pork-curing Processes on Trichinae, B. H. Ransom, B. Schwartz, H. B. Raffensperger, Department

Bulletin, 880, 1930; Pig Parasites and Thumps, B. H. Ransom, Yearbook of Agriculture, 1920; pp 175-80, 1921.)

Meat Inspection and Stamping

We return now to more of Dorset's work, or that done under his direction.

At the time the Federal meat-inspection law was passed, in 1906, all meats which were officially inspected were marked by means of a label known as the Howard label, printed in a transferable ink on soluble gelatin. These labels were not wholly satisfactory because they frequently failed to leave an imprint and at times could be removed and reapplied by anyone so inclined. Furthermore, the Department of Agriculture in the year ending June 30, 1907, expended more than $158,000 for these labels, which were manufactured by a private firm.

In the year 1906, Dr. Dorset, Chief of the Biochemic Division, devised a marking fluid which was both indelible and harmless and which could be applied to meats when wet or dry, warm or cold, to produce a legible inspection mark. In a short time this fluid completely replaced the Howard label. The saving effected has exceeded several million dollars. It was estimated that if the Department continued to use labels at the price it was paying at that time, it would, with the greatly increased scope of the inspection, be forced to expend approximately $500,000 per annum for marking all inspected meats.

Pullorum Disease Control

Control of pullorum disease is of vital importance to a profitable poultry industry. The germ is harbored in the ovaries of infected hens

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Control of pullorum disease is of vital importance to a profitable poultry industry. The germ is harbored in the ovaries of infected hens

and transmitted by them to their offspring through the egg. Organized control of pullorum disease began with the introduction of a laboratory test known as the tube agglutination test. Later, the rapid serum test was developed but as it was virtually a laboratory test its usefulness was limited. Bureau scientists under Dorset's supervision then directed their attention to the development of a test that could be used on farms as well as in the laboratory.

Between 1929 and 1931 this research resulted in the development of a much simpler test that could be completed within a few minutes on poultry farms. It involved the use of a biological product known as an antigen, and a dye that enabled the agglutination reaction to be easily seen. This "rapid whole blood test for pullorum disease" is now extensively used by State agencies that are cooperating with the Bureau in official pullorum-disease-testing programs. The extensive application of the method is indicated by the establishment of training schools in many of the States at which pullorum-testing agents are instructed in the operation of the test. Its use has saved the poultry in industry millions of dollars.

Conquest of Bovine Tuberculosis

Various kinds of tests have done much to facilitate the progress of mankind. Some are of simple mechanical nature; others relate to specialized sciences. The chemical test for determining butterfat in milk is a familiar example. Another is the tuberculin test, widely used during more than a quarter-century as a basis for the eradication of bovine tuberculosis from the United States. The test is based on well-established

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<u>Control of Bovine Tuberculosis</u>

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scientific principles and has been applied successfully in the course of testing more than 200,000,000 animals.

Tuberculin was discovered by the eminent scientist, Robert Koch, in 1890. Three years later the Bureau of Animal Industry began to produce it. Its laboratories have been producing it ever since. Tuberculin contains a small quantity of the material derived from the growth of the germs, but never the germs themselves, either living or dead. Nor does the product contain any substance that can have any detrimental effect on a nontuberculous animal.

However, animals that are tuberculous are affected by injections of tuberculin because of a specific sensitiveness to this biological product. The tuberculous animal is much like a person who is susceptible to hay fever. Whereas the pollen of ragweed or other plants may cause a violent reaction in the susceptible hay-fever patient, such weeds have no effect on unsusceptible persons. An analogous condition exists in connection with tuberculosis and tuberculin.

Through research by Marion Dorset and members of his staff, tuberculin is now produced on a synthetic medium which results in a more potent product than that formerly produced on a beef-broth medium. So effective is the improved tuberculin that animals frequently react to it even though lesions of the disease are too small to be visible on post mortem examination.

Nevertheless the evidence of the value of tuberculin is so conclusive that court decisions have upheld tuberculin testing and the resulting condemnation of tuberculous animals. The evidence of Federal meat inspection likewise shows definitely that the detection of tubercu-

losis in cattle by means of the tuberculin test, together with the removal of reactors, has greatly reduced the extent of this disease in the United States so that it no longer causes losses of commercial significance from a meat-packing standpoint.

Conquest of bovine tuberculosis in the United States resulted from a combination of public sentiment, research work, and well-organized field activities planned by Federal and State veterinary officials. The tuberculin testing of cattle for detecting the disease began in 1892 on a farm in Pennsylvania. Of 79 animals in the herd, 30 reacted to the test. Later testing in 11 other States disclosed large numbers of reactors with percentages ranging between about 4 and 50. Post-mortem examinations supported the general accuracy of tuberculin testing. In 1910, the Bureau of Animal Industry began the systematic tuberculin testing of cattle in the District of Columbia as a means of suppressing the disease through the detection and removal of affected animals. By this means the percentage of reactors decreased from nearly 19 in 1910 to less than 1 in 1917, and to a small fraction of 1 percent about 5 years later and subsequently.

Following a thorough study of the tuberculosis situation by Federal and State veterinary officials, the United States Livestock Sanitary Association, in December 1917, formulated a specific program entitled Uniform Methods and Rules for Tuberculosis-free Accredited Herds. This program provided briefly for the testing of herds and for official recognition, as accredited, of those from which tuberculosis was eradicated. An allied feature of the plan was provision for eradicating tuberculosis from larger areas such as entire counties.

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It was not until 1919 that concerted efforts to test all cattle within a given county were begun. Developments in the campaign have included the testing of all of the cattle in all herds and counties in the United States. By this means, together with the removal and slaughter of reactors, the infection was reduced from as much as 30 percent in some parts of the country to the present small fraction of 1 percent in all parts of the United States. Related work has dealt with the eradication of tuberculosis from swine and poultry.

The Nation-wide campaign to eradicate bovine tuberculosis has had an important practical bearing on the value of animals, their salability, and on profitable outlets for livestock and dairy products. Although an insidious disease of high morbidity, tuberculosis has been practically eradicated from all herds in the United States by repeated tests and the removal of reactors.

Direct benefits to cattle owners include increased values of breeding stock ranging between $10 and $25 a head and the indirect benefits include a broadening of outlets for livestock products, often to the extent of establishing new local industries, such as creameries, cheese factories, and similar establishments. In one county in Tennessee a bank official stated that the deposits in his institution had increased 20 percent since that county had been freed of tuberculosis among cattle.

"The Jungle" and Meat Inspection

Agitation and public sentiment for the inspection of meat began, in the United States, as early as 1861. The sentiment was based on the alleged unwholesomeness of meat from animals subjected to cruel treatment

It was not until 1917 that concerted efforts to test all cattle within a given county were begun. Developments in the campaign have included the testing of all of the cattle in all herds and counties in the United States. By this means, together with the removal and slaughter of reactors, the infection was reduced from as much as 50 percent in some parts of the country to the present small fraction of 1 percent in all parts of the United States. Related work has dealt with the eradication of tuberculosis from swine and poultry.

The Nation-wide campaign to eradicate bovine tuberculosis has had an important practical bearing on the value of animals, their salability, and on profitable outlets for livestock and dairy products. Although an insidious disease of high morbidity, tuberculosis has been practically eradicated from all herds in the United States by repeated tests and the removal of reactors.

Direct benefits to cattle owners include increased values of breeding stock ranging between $10 and $25 a head and the indirect benefits include a broadening of outlets for livestock products, often to the extent of establishing new local industries, such as creameries, cheese factories, and similar establishments. In one county in Tennessee a bank official stated that the deposits in his institution had increased 50 percent since that county had been freed of tuberculosis among cattle.

<u>The Jungle and Meat Inspection</u>

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in transit to market and on reports from health officers that diseased animals were being slaughtered for food.

In 1870 the Commissioner of Agriculture, Horace Capron, said, in urging the establishment of a veterinary division in the Department of Agriculture, "The value of stock lost annually from disease is enormous and threatens not only to decimate the animals but to expose the human family to disease from the consumption of unwholesome meats."

Public sentiment finally led to the first legislation providing for Federal meat inspection, which was passed by Congress in August 1890. This Act was only a feeble attempt to meet public needs, so the appeals increased from livestock interests and the packing industry for a service that would inspect and certify to foreign governments the healthfulness of animals and the wholesomeness of meats from the United States.

On March 3, 1891, Congress passed a somewhat broader and more effective law, largely to provide inspection that would command the confidence of European purchasers of products from this country. The first inspection under that legislation was in New York City, May 12, 1891, and was confined to export dressed beef. About a month later inspection was inaugurated in Chicago, and soon thereafter at five other points.

As a result of further agitation and action by Congress, the Meat Inspection Act of June 30, 1906, became a law and provided the basis for the present extensive and thorough meat inspection service. Upton Sinclair's widely read novel, The Jungle, descriptive of the stockyards district of Chicago, is credited with much of the favorable support received by that legislation. President Theodore Roosevelt is given credit for his

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enthusiastic support in translating public sentiment into legislation. The Secretary of Agriculture, whom the law empowered to provide inspection, designated the Bureau of Animal Industry to take on the enlarged duties and responsibilities. The conduct of the work is fully described by reports and other publications of that Bureau. The service was transferred to the Food Distribution Administration early in 1943.

Brucellosis, Undulant Fever, and Strain 19

The Bureau of Animal Industry has conducted scientific studies with brucellosis in domestic animals since about 1900. At that time the malady was commonly known as contagious abortion, later as infectious abortion, then as Bang's disease, and finally as brucellosis in recognition of Sir David Bruce who discovered the first species of the genus in which the organism is classified. The causative agent of the disease is closely allied to that causing undulant fever in man.

The conquest of brucellosis in domestic animals is being accomplished mainly by the application of knowledge obtained through painstaking research. Neither casual observation nor close examination of affected herds has provided a basis for successful control measures. That is because the disease often enters a quiescent stage after causing extensive losses, the infective organisms still being present though their manifestations have subsided.

Scientific research on brucellosis involved first the use of various chemicals and drugs, some of which had been advanced and hailed as curative agents but which failed, in tests, to reduce the number or virulence of

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the Brucella organisms. Research workers then turned to the study of bacterins, vaccines, and serum therapy. Experimental work directed by Schroeder, Cotton, and Buck, of the Bureau staff resulted in the accumulation of extensive data and finally in the discovery, by John M. Buck, that one of his many cultures of the Brucella organism, designated as strain 19, retained the same characteristics over a long period.

When cultured over and over, this organism, unlike others, maintained the same virulence. Moreover, the virulence was too mild to cause the disease but sufficient to create a reaction to the agglutination test that is used in detecting animals that harborthe germ.

To be doubly safe, Dr. Buck decided to conduct his immunizing tests with calves about 5 or 6 months of age, before the udder developed to its normal size and function. This procedure prevented any possibility of infection occurring in the udder and later gaining access to the milk. This line of research resulted in the production of a vaccine which, in experiments of limited scope, proved highly encouraging as a means of combating brucellosis. The success of further early tests caused cattle owners to offer their herds for more extensive field trials, which likewise were successful.

Data on approximately 260 infected herds in 24 States and involving more than 17,000 calves showe that when the calves matured and were bred, about 96 percent of them had normal pregnancies. Of the abortions that occurred, only a small percentage could be traced to Brucella infection. These favorable results led to the adoption in 1940, of calfhood vaccination, under proper supervision, as an adjunct to the previously

established test-and-slaughter plan of combating brucellosis.

Developments have shown the effectiveness of vaccination in attaining desired results. An interesting sidelight has been the subsequent use of vaccine prepared from the same strain, No. 19, pf the organism by the British Ministry of Agriculture and Fisheries in combating brucellosis in England as an aid to wartime milk production.

Foot-and-Mouth Disease Blitzes

Foot-and-mouth disease is another contagious and disastrous ailment of cattle. Some countries battle it all the time and their cattle are never free from its ravages. The death rate itself is from 6 to 20 percent of the animals affected, but animals that recover are far from normal. They are poor milk and beef producers, they abort readily, they often have ill-shaped feet or are crippled. If the disease were permitted to go unchecked it would soon ruin the cattle, swine, and sheep industries.

For a long time this country has maintained a rigid quarantine against the disease and animals here are doubtless more susceptible than those in countries where it is constantly present. The slightest laxity in vigilance against the entry of the virus into this country would invite serious consequences. The scientists of the Bureau of Animal Industry have evolved an astonishingly effective method of eradicating the plague when it does enter as it did in 1902, 1908, 1914, 1924, and 1929.

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United States Department of Agriculture," by Peter K. Olitsky, Jacob Traum, and Harry W. Schoening.)

Once the disease is diagnosed in cattle anywhere in the United States the Bureau uses blitz tactics to put this information to practical use. The infected and exposed herds are slain, and the carcasses are either burned or buried in quicklime in long mechanically dug trenches, Owners are paid for the animals at their appraisal value. The scientists have found that ordinary lye solution destroys the virus in less than 10 minutes, thus replacing the more expensive disinfectants--cresol, and bichloride of mercury--at savings of thousands of dollars during serious outbreaks.

Marriage, Inbreeding, and Guinea Pigs

For centuries the subjects of inbreeding and crossbreeding have been topics of public discussion, often culminating in laws and customs relating to marriage. Primitive peoples had definite views on the degree of inbreeding that was permissible from social and physical standpoints; and customs of different peoples have varied widely; some are designed to prevent inbreeding whereas others appear to favor it.

In the production of livestock, opinions of breeders likewise have differed. Some have held that inbreeding is likely to produce progressive degeneration evidenced by reduction in size, constitutional vigor, and fertility, and leading ultimately to the appearance of monstrosities. On the other hand, most of the modern improved breeds of livestock originated through rather close inbreeding of selected stock.

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Heredity, Inbreeding, and Hybrid Vigor

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To provide a basis of fact for ascertaining the merits of various opinions, the Bureau of Animal Industry, as early as 1906, began a comprehensive study of the effects of inbreeding, using guinea pigs as material because they are cheap, easy to handle, and multiply rapidly. Twenty-three separate families were started, each from a single pair of guinea pigs, and were maintained exclusively by matings of brothers with sisters. In 1917, 17 of these families were still on hand and one of the families had reached the twenty-fifth generation of inbreeding. Most of the experimental work was conducted by Sewall Wright and the results of the inbreeding and crossbreeding studies appear in two professional papers, Department Bulletins Nos. 1090 and 1121.

By 1924 more than 35,000 animals had been studied in connection with the breeding work. The results showed, in general, that inbred stock suffered a genetic decline in vigor in all characteristics, as compared with control stock. In outward appearance, as shown by color and pattern, each line of descent tended to become fixed. In some cases an entire family bred true to a given color and pattern. Relatively few monstrosities were produced either by the inbred families or by the controls. Even two of the feeblest families gave few or no pronounced abnormalities.

The results of the study, as interpreted by Dr. Wright, point the way to important applications of inbreeding in the improvement of livestock. He found that more than 90 percent of individual variation in the rate of gain and size of litter is determined by external conditions. Progress by ordinary selection of individuals thus is likely to be very slow or nil. Consequently a single unfortunate selection of a sire, good as an

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individual but inferior in heredity, is likely to undo all past progress.

On the other hand, by starting a large number of inbred lines, hereditary differences in various respects are brought clearly to light and fixed. Crosses among these lines may be expected to give a full recovery of whatever vigor was lost by inbreeding, and particular crosses may safely be expected to show a combination of desired characters distinctly superior to the original stock. Thus a crossbred stock can be developed which can be maintained at a higher level than the original stock, one that could not have been reached by selection alone.

Further improvement is to be sought by the isolation of inbred strains from the improved crossbred stock, followed ultimately by crossing and selection of the best crosses for the foundation of new stock. This method of improvement, established scientifically, is the way in which most of the recognized breeds of livestock were actually developed. The relatively few promising families and successful matings between them were the foundation stock of many breeds.

Soft-Pork Investigations

The "soft-pork problem" involves particularly hogs that have been fed chiefly on soybeans and peanuts. Cooperative research by the scientists of the Bureau of Animal Industry and of the experiment stations of the Southern States have disclosed means by which the undesirable condition may be avoided. This work began in 1919 and was continued many years.

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Carcasses and products of hogs that have received so-called "softening" feeds have certain undesirable characteristics, as judged from a commercial standpoint. There is a lack of firmness in the fat which may be so extreme as to cause shapelessness in the products. This makes them inconvenient to handle and unattractive to many persons. Lard from soft or "oily" carcasses is sometimes fluid or semi-fluid at room temperatures.

The solution of the problem consists largely in providing a system of feeding that regulates the intake of softening feeds, in relation to feeds that produce firm carcasses, and that takes into account the age of the animal, length of feeding period, and period of final fattening, There is a direct relation, for instance, between immaturity and softness in pigs. The soft-pork problem is also fundamentally a problem of fat metabolism.

A mixture of 5 parts corn meal and 1 part peanut meal, self-fed with or without supplementary minerals, to pigs starting at approximately 80 pounds weight and making gains of approximately 100 pounds through a feeding period of from 9 to 10 weeks produces, in the usual case, hard or medium-hard hogs. Peanuts grazed or self-fed with or without supplementary minerals for a period of 60 days to pigs starting at approximately 100 pounds in weight produce soft carcasses. It is impossible to produce hard carcasses by feeding corn and tankage or corn and cottonseed meal to such soft hogs for a later period of 60 days, although the soft hogs are made firmer by subsequent feeding of hardening feeds.

Fishmeal, Pork, and Sour Hams.

Experimental work conducted with the Department's herd of swine at Beltsville, Md., showed that fishmeal has a value equal to that of tankage as a corn supplement. The experiments showed also that fishmeal when fed to hogs does not impart a fishy flavor to the pork. During the calendar year 1940 the domestic production and importations of such fishmeal totaled approximately 218,000 tons.

Around 1929 and 1930 the packing industry was experiencing considerable loss from the souring of hams during the curing process. Upon investigation of the problem, scientists in the Bureau of Animal Industry found that the organisms which cause ham souring are present in the living animal and that the souring process could be prevented by rapid chilling of carcasses immediately after slaughter. As the packers are now placing freshly dressed carcasses into the cooling rooms as soon after slaughter as possible, the losses from this cause that amounted to $650,000 in one year, are being avoided.

Diseases of Horses

The development of an improved, reliable antigen with good keeping qualities for use in the complement-fixation test for dourine and the improvement of the technique of this test have made possible the testing of large numbers of samples in a very brief period (as many as 2,500 in a day), and this has resulted in the prompt and adequate control of this contagious venereal disease of the horse. As there is at present

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no effective treatment, control by the test-and-slaughter method is the approved means of handling dourine. Control of this disease has saved the horse-breeding industry millions of dollars.

Investigations of equine encephalomyelitis produced evidence that a safe and efficient vaccine could be prepared. In 1934 the formolised brain vaccine was introduced; it has been commercialized and widely used. Improvements were made by Bureau research workers and others and the chick embryo vaccine was available in 1938. It is estimated that approximately $1,000,000 is saved annually as a result of these studies together with those of other encephalomyelitis researches, such as the discovery and location of the two types of virus.

From Lincoln's Mother to Tremetol

A condition of animals and persons commonly known as milk sickness or trembles has been observed in various rural areas as long ago as colonial days. According to tradition and observations by physicians and others, the milk of cows in some sparsely settled areas was suspected of poisoning persons who drank it, hence the name milk sickness.

It was observed also that suckling calves sometimes sickened and died of a condition known as trembles, named because of the violent trembling, that was one of its symptoms. Various plants, such as poison ivy, water hemlock, Virginia creeper, marshmarigold, and mushrooms were suspected of affecting milk produced by cows that had eaten such plants, but the cause proved to be difficult to trace. Some observers argued that the disease was caused by molds or parasitic fungi that grew on the plants.

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Research conducted largely in the Bureau by C. D. Marsh, J. F. Couch, and A. B. Clawson, and published in 1933, demonstrated that milk sickness is caused principally by two plants which contain a chemical compound known as trematol; it was crystallized and its structure was determined. One of the plants is white snakeroot, Eupatorium urticaefolium, which occurs widely throughout the eastern part of the United States and as far west as Minnesota, Nebraska, Oklahoma, and Texas. The other plant is jimmyweed or rayless goldenrod, Aplopappus heterophyllus. This plant grows from southern Colorado to western Texas, New Mexico, and Arizona, and extends southward into Mexico.

Further research showed that, although cows can secrete the poison in their milk, it is unlikely that the meat carries enough trematol to cause the sickness. Milk sickness, or trembles, can be completely prevented by keeping livestock away from patches of white snakeroot in the East and jimmyweed in the Southwest. Another plant botanically related to jimmyweed but having no well-known common name is Aplopappus fruticosus. This plant also may furnish the poison, although it is a less common cause than the other two. The disease in livestock can be prevented by keeping animals away from the plants, either by fencing off the areas where they grow or destroying the plants.

Thus science has cleared up a mystery and provided factual information for preventing sickness in man and animals. Early writers reported that whole villages were at one time depopulated by the disease and settlers were terrified by the "frightful pestilence." It is reliably reported that the deaths of Abraham Lincoln's mother and two of her kinsfolk

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were caused by milk sickness.

Phenothiazine, Death on Worms

Phenothiazine is a synthetic organic chemical that was first prepared in the latter part of the nineteenth century. It is closely related to the thiazine dyes of which methylene blue is perhaps the most widely known. Its value as an insecticide was recognized some years ago, but, as prepared for this purpose, the drug contains a conditioning agent which renders it unfit for use as an anthelmintic, a use discovered in 1940 by workers in the Bureau of Animal Industry.

Phenothiazine shows promise of becoming the most valuable substance so far discovered for the removal of parasitic nematodes from domestic animals, especially from ruminants and equines. In tests with the different species of animals, therapeutic doses of phenothiazine, with few exceptions, have been essentially nontoxic. Most of the Bureau's early studies with phenothiazine were conducted by Paul D. Harwood, of the Zoological Division. The discovery led quickly to the manufacture of the drug in commercial quantities and production is now conducted on a vast scale.

Whereas other anthelmintics are commonly effective only against a single parasite, phenothiazine has proved to be valuable in removing various kinds of parasites from several species of animals. In sheep, this drug is effective against the common stomach worm, the lesser stomach worms, bankrupt worms (so named because of the bankrupting effect of the worms on flock owners), the hookworm, the nodular worm, and others. In cattle

phenothiazine is efficacious for the removal of stomach worms, nodular worms, and hookworms. In swine, the chemical removes nodular worms and is partially effective against mature ascarids. In horses, the chemical removes nodular worms, is partially effective against mature ascarids, and is effective against large and small strongyles. Phenothiazine is effective also for the removal of cecal worms in poultry, and partially so against roundworms.

A noteworthy wartime angle is the effectiveness of phenothiazine against nodular worms of sheep. These worms cause serious injury to the intestines thereby reducing their value for casings and suitability for surgical sutures. Prevention of nodular worm disease in sheep, therefore, is a distinct contribution to the war effort for there has been a great decrease in imports of sound casings for the production of surgical sutures.

It is estimated that more than a million pounds of phenothiazine were manufactured and sold during 1941, the commercial value of which was about $650,000.

Naturally this account of research by scientists in the field of animal industry is incomplete, touching only the high lights and giving brief expositions of only the most important fundamental research. It is impossible to trace out in all ramifications either the economic value or the catalytic effect of these findings on research in related and in unrelated fields. In war and in peace such work has results of never-ending value and importance.

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SECTION III

THE EXPERIMENT STATIONS

The passage of the so-called Hatch or Agricultural Experiment Stations Act of March 2, 1887, was the result of prolonged agitation by many individuals among whom W. O. Atwater, professor of chemistry at Wesleyan University, Middletown, Conn., the first Chief of the Office of Experiment Stations, was prominent. The Act authorized the establishment, under the direction of the land-grant colleges, for which provision had been made by the Act of July 2, 1862, of State experiment stations to conduct experiments relating to agricultural subjects.

By the act the States were to receive specified Federal grants annually to aid in establishing and maintaining agricultural experiment stations. A main difficulty in the Department's work had been the lack of well-coordinated facilities within the individual States to cope with diverse topographical and climatic conditions. The Land-Grant College Act had, however, given impetus to State agricultural research. By 1886 the field was well prepared for the establishment of some national agency to coordinate the work of existing State agricultural experiment stations for the maintenance of which Federal aid was increasingly demanded.

Largely through Commissioner Colman's personal interest a convention had been held on July 8, 1885 to consider the establishment of State experiment stations with Federal aid. A second convention of delegates from the States was called for Oct. 18, 1887, at which time a permanent

organization was effected and named the Association of American Agricultural Colleges and Experiment Stations. In the meantime passage of the Hatch Act on Mar. 2, 1887 authorizing Federal grants for State work in agricultural research required some response in Department organization.

Thus it was that W. O. Atwater was made Chief of a new Office of Experiment Stations, established Oct. 1, 1888, with A. C. True as his associate. It was the Department's function to act in an advisory capacity, to furnish forms for the tabulation of research results, to indicate fruitful lines of inquiry, to coordinate the work and prevent duplication of effort, and to give advice and assistance to the stations. At the end of 1888 there were 46 experiment stations in the United States, 43 of which received the Hatch Fund.

Subsequent passage of the Adams, the Purnell, and the Bankhead-Jones acts granted further funds for agricultural research to the States and Territories. Examination and approval of research projects in advance of the expenditure of funds and the review of the work and examination of expenditures at each station have been continuing responsibilities of the Office of Experiment Stations as the representative of the Secretary of Agriculture in the administration of these acts. Programs of research with proposed expenditures under Federal funds are submitted by each station for review and approval at the beginning of each fiscal year. Alaska, Hawaii, and Puerto Rico also receive Federal grants for experiment stations.

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Beginnings of the Office of Experiment Stations

The first agricultural experiment station actually established in the United States was in Connecticut in 1875. The first aim of the Office of Experiment Stations was to act as a clearing house and exchange for the numerous stations existing when it was created. However, investigations of human nutrition, home economics, irrigation, and farm drainage were carried on in the early years by the OES itself. In 1888, Commissioner Colman wrote of the Hatch Act that: "The path to success in this experiment-station enterprise passes by the fountains of abstract science and by the farms and firesides of the American people."

In 1889, Secretary Rusk, following a suggestion of Dr. Atwater and the Department, began to issue Farmers' Bulletins. The first two of these discussed the nature and work of the experiment stations. In 1891, A. W. Harris took over as Chief of OES with Dr. True still the associate. During this time a compilation of the analyses of American feedstuffs had been issued, and a bulletin on milk fermentation by H. W. Conn. Many other important and useful publications followed.

It was about 1894 that the investigation of human nutrition got under way. In that year also the new Assistant Secretary of the Department, Charles W. Dabney, formerly President of the University of Tennessee, was named head of all the Department's scientific work including that in OES.

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On July 1, 1915 the States Relations Service was formed and the Office of Experiment Stations became part of that. On July 1, 1923, the OES again became independent with the dissolution of the States Relations Service.

Career of a Leader

Dr. Atwater had studied in Europe where he became acquainted with the agricultural experiment stations of which there were 30 on the Continent by 1866. He had also displayed an early interest in the analysis of foods. Between 1879 and 1883 he had made a series of analyses of fish for the United States Fish Commission and of the flesh of animals for the Smithsonian Institution. His dietary studies for the Massachusetts Bureau of Statistics and Labor were published in 1896.

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Other States then began to establish experiment stations in rapid succession. After passage of the Agricultural Experiment Stations or Hatch Act the Storrs Agricultural Experiment Station was organized by act of the Connecticut Legislature and Atwater continued his work there. Then Commissioner Colman called him to Washington to head the new Office of Experiment Stations, though he accepted this position only with the understanding that he could remain director at Storrs and professor at Wesleyan.

Early Work of the Office of Experiment Stations

Immediately after its establishment the OES began to assemble information regarding the organization, revenues, work, equipment, and publications of the agricultural colleges and experiment stations. An address list of the stations was soon published, and this was followed by an organization list. Both Farmers' Bulletins and technical monographs were issued by the OES, the former to present results in plain form so that intelligent farmers would readily understand, and to be both brief and practical.

It took the OES about 5 years to perfect its organization and develop its publications. In 1889 the first number of the Experiment Station Record appeared. It was 1889 before the Farmers' Bulletins actually began to appear. Between 1897 and 1913 the Office also contributed to the Farmers' Bulletin series 76 numbers of a subseries on Experiment Station Work. Each number contained several brief popular articles based on the practical work of the experiment stations and kindred institutions in other countries.

The OES also published a considerable number of technical bulletins, among them large monographs such as Bulletin 28, on the chemical composition of American food materials, first issued in 1896 and repeatedly revised; Bulletin 33, on the cotton plant, published in 1896; Bulletin 45, a digest of metabolism experiments with men and domestic animals, published in 1897; and Bulletin 80, on the history of the agricultural experiment stations up to 1900.

The Office of Experiment Station's staff began to make annual inspections of station work and expenditures in each State in 1894. This duty is performed by the Director of the Office and his principal scientific assistants, in conferences with the station staffs regarding their lines of work, material equipment, personnel, publications, financial needs, and so on. The functions of the Office as a clearing house of information and consultation on a great variety of matters relating to agricultural research throughout the world have grown steadily.

"The Babcock Test," A Result of Research In Early Days

An extraordinarily well-known piece of research done early in experiment station history was the development of the test for readily determining the butterfat content of milk. Through research by Stephen Moulton Babcock of the Wisconsin Agricultural Experiment Station this test was perfected. Announcement was made in July 1890 and it has since been called the "Babcock test." It is universally used.

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purchased by weight or volume, regardless of the butterfat content, which was a serious handicap. Dairymen who produced high-standard milk bitterly regretted its mixture with low-fat milk. They believed that creamery patrons should be paid for their milk and cream in exact proportion to its true value.

Babcock's investigations produced a new method for the estimation of fat in milk, especially adapted to creameries and cheese factories. It replaced inefficient, time-consuming tests with one that was accurate and so rapid it could be carried out in 5 minutes. No change has been made in its essential features to this day. Its influence was tremendous.

The Babcock test and the cream separator together tended to determine the course of the dairy industry and to foster the development of cooperative dairy manufacturing. They increased milk production through facilitating study of individual cow performance. Dairy breeds were improved for milk production, the unseparated cream in skim milk was reduced by one-half, and even soil fertility was conserved through expansion of dairying. The economic return from the test, though it cannot be expressed in dollars and cents, was huge.

Early Nutrition Research in the OES

Because the work of the OES in its relations with the State experiment stations touched lines of work for which the Department of Agriculture at the time had no organization, there was a growing tendency for a number of years to put under that Office special investigations for which Congress provided funds. The first of such investigations dealt with human

nutrition. Irrigation, drainage, incipient agricultural engineering, and others followed. Each of these lines of work is treated elsewhere in this publication under its appropriate subject-matter head.

The nutrition work grew directly out of studies made at Wesleyan University, in conjunction with the Storrs Experiment Station. The results of these studies attracted the attention of the Hon. Edward Atkinson, of Boston, Mass., who had compiled data on the subject from foreign sources, and had been interested also in the experimental and practical work of the New England Kitchen, conducted in Boston by Mrs. Ellen H. Richards, in collaboration with the Massachusetts Institute of Technology.

Mr. Atkinson prepared a paper: "Suggestions for the Establishment of Food Laboratories in Connection with Agricultural Experiment Stations," which became Bulletin 17 of the OES. Secretary Morton, and even the President of the United States, Grover Cleveland, became interested in the matter and the former requested an appropriation for nutrition investigations; $10,000 was granted for the fiscal year 1894. Dr. Atwater assumed supervision of this work, carrying it on at Middletown, Conn., with the facilities of Wesleyan University and the Storrs Experiment Station.

It consisted of collecting information regarding available foods and their uses; dietary studies among rural and urban people; digestion and metabolism experiments; experiments on the nutritive value of foods; the compilation on a broad scale of analyses and the results of experiments in this country and abroad; and the improvement of methods and apparatus

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for nutrition work. The work continued under Atwater until he was incapacitated by a stroke in November 1904. Later it was brought to Washington. Dr. Atwater died September 22, 1907.

As early as 1875-76 Dr. Atwater also laid out the objectives of the experiment station system about as they would be outlined today. He made scientific research their primary objective. He also planned and supervised nutrition investigations carried on in about 20 States. In the judgment of competent experts the nutrition investigations conducted under Atwater's direction were more thorough in their scientific methods, more extended in scope and amount, and more useful in practice than any other inquiry of the kind previously undertaken in this country or in Europe.

Irrigation and Drainage Investigations

With the spread of irrigation in the Western States during the latter half of the nineteenth century many problems arose regarding available water supply, water rights, the control of the appropriation and distribution of water, irrigation practice and methods, the quantities of water required by different crops, and so on. About 1896 the OES was called upon to extend its work in this field, and in the appropriation act of the Department for the fiscal year beginning July 1, 1898, there was included an item of $10,000 for irrigation studies.

Specifically the Department was directed to collect from agricultural colleges, experiment stations, and other sources, valuable information on the subject of irrigation, which was to be published in bulletin form.

It could use special agents for this work which Secretary Wilson assigned to the OES. It conducted such investigations for 16 years. They were transferred to the Office of Public Roads in 1915 where they were continued.

Passage of the Reclamation Act of 1902 gave additional impetus and importance to these studies. Largely through them improved legislation was enacted in the arid States and the general principle of determining water rights according to the actual and beneficial use of water was firmly established. There followed other studies which resulted in far more economical use of the limited supplies of water available for irrigation. Studies of water loss in transit from stream to farm led to improved conduits. Devices for measuring water were tested and new ones developed. Much of this work was done with State cooperation.

Realizing the danger to agriculture under irrigation in lack of drainage the OES gave attention to this subject. In 1902, C. G. Elliott, an experienced drainage engineer and author of Farmers' Bulletin No. 40 on farm drainage, published in 1896, joined the irrigation force of the OES. Under his leadership, work relating to drainage was greatly expanded and in 1907 became a separate Division of the Office where it continued until 1915 when it also was transferred to the Office of Public Roads.

During this 13-year period much progress was made toward a better understanding and solution of drainage problems on irrigated lands that had been injured by seepage and alkali, and toward the wider use of tile drainage, especially in the Southern States. Drainage systems were also surveyed and planned on large scale, involving community effort and the formation of drainage districts.

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In at least eight States general laws for the establishment of drainage districts, and for financing these districts through the issuance of bonds, were enacted, mainly as a result of the information acquired and disseminated by OES drainage engineers. Under these laws hundreds of drainage districts were formed and hundreds of thousands of acres of swamp and overflowed lands were reclaimed.

Important Research Accomplishments of Insular and Territorial Stations

Following early demonstrations in the Southern States and at the Federal Puerto Rico Station that cattle ticks could be controlled by the use of dipping tanks, the livestock industry developed rapidly on the Island and dairying became possible. Improved forage plants were likewise introduced. The Station led in the investigations which made these developments possible. It has also assisted materially in developing the Island's citrus industry and in establishing vanilla growing as a profitable undertaking, and it introduced Uba sugarcane which is resistant to mosaic disease and is widely planted.

The giant toad (Bufo marinus) was first introduced and colonized in Puerto Rico from Barbados about 1920 by the Federal Experiment Station at Mayaguez. The purpose of the introduction was to reduce the numbers of several major crop pests such as white grubs, mole crickets, weevils, and cockroaches. The frog has proved a predator of great value and is now well established in Puerto Rico. This has become one of the outstanding examples of the biological control of insect pests. As a result, the white grub has actually ceased to be a problem in the agricultural parts of the Island.

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Another important recent accomplishment of the Mayaguez Station was its development of USDA-34 sweet corn from sugary seeds found on a native variety. This was a great step forward in producing a corn which could be grown under tropical conditions. It has proved of inestimable value not only to Puerto Rico but to Hawaii and other warm-climate areas.

The Hawaii Station found, some years ago, that a disease which was doing great damage to pineapples was due to excessive manganese in the soil. It demonstrated that spraying the plants with iron-sulfate solution corrected the trouble. These discoveries made possible the replanting of more than 10,000 acres on which pineapple growing had been abandoned because of the disease.

The Station also showed the value of cover crops in the Tropics and of rotations for sugarcane and pineapples, the leading crops of Hawaii. This was instrumental in widely extending their use. The superiority of ammonium sulfate over nitrate of soda for fertilizing rice was another important result of the work of this station.

The investigations in Alaska have demonstrated that in many parts of the Territory agriculture can be made to supplement other industries which may become established there by providing much of the local food requirement. This fact was held in doubt by many people at the time investigations were started there in 1898. Crops have been selected and methods of growing them developed for the Matanuska and Tanana valleys of southeastern Alaska and to a limited extent for Kodiak, and livestock has been maintained for a sufficient period to support this assertion. Considerable aid has also been given to the important enterprise of fur farming in the Territory.

Cooperative Work on Cotton

Both domestic cotton manufacturers and foreign markets complained of apparent deterioration in American cotton about 15 years ago. Funds under the Purnell Act were made available for study of the problem in several cotton-growing States and in 1928 most of these States cooperated with the Department in securing adequate samples of the cotton crop to ascertain its quality. This was the first authentic record of the quality of cotton produced in any country.

As a result of the records then made areas could be plotted which produced high-quality and poor cotton, thus pointing out opportunities for improvement in specific localities. Under the program which followed, southeastern States have materially increased their production of the high-quality cotton required by local mills.

Research was also applied to the properties of cotton fibers associated with superior spinning quality. As a result, tangible measurement of cotton quality as related to strength, waste reduction, and spinning economy became possible. This information has been widely applied by cotton-breeding specialists.

Disease-Resistant Varieties

The OES had its part in cooperative projects concerned with the breeding and development of disease-resistant strains of economically valuable plants. The State experiment stations have had constantly to meet relatively localized situations by carrying on long and complicated jobs of selection and breeding for resistance. American agriculture has

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benefited markedly. This cooperative work included the breeding of curly-top-resistant beet varieties and the highly successful domestic sugar-beet-seed program mentioned elsewhere. The latter stemmed from cooperative experiments between the Division of Sugar Plant Investigations in the Bureau of Plant Industry and the New Mexico Agricultural Experiment Station.

Factors Influencing Meat Quality and Palatability

A study of the factors influencing the quality and palatability of meat was selected as one of the subjects for cooperative investigation by State experiment stations and the Department after the passage of the Purnell Act. No scientific basis then existed for current marketing customs, practices, and prejudices concerned with the purchase and use of animals and their meat which had grown up over the years. The objective of the work was to ascertain the factors in meat that are responsible for quality and palatability, and how these could be modified by breeding, management, and feeding of livestock, or in the handling and processing of the meat.

One of the oldest prejudices held in effect, that grass-fed cattle always produced dark-colored meat. Results of studies at the Kansas and West Virginia Stations proved this false. They showed that the color of fat and lean was in general related to the degree of finish. Investigations at the Nebraska, Missouri, and Illinois Stations revealed that discrimination by packers against heifer carcasses was justified only from the standpoint of more waste to cuts of meat.

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This finding resulted in very large returns to cattlemen who produced finished heifers. Improved methods of chilling, preparing, and preserving farm meats, an outgrowth of the study, have been calculated to add 15 percent to the number of meals obtained from farm-slaughtered animals. If the calculation is applied only to hogs slaughtered for home consumption it would indicate a return to farmers of $3,450,000 annually.

Results obtained at the Indiana, Mississippi, and Tennessee stations showed that suckling lambs on good pasture grew as well and were as fat as similar lambs fed grain while on pasture. The annual saving in cost of feed under these conditions had been estimated to amount to $1,250,000.

Hybrid Corn

The Nation-wide survey in 1942 by the Department of Agriculture revealed that 40,773,000 acres or about 44.8 percent of the 91,098,000 acres of corn in the United States were planted with hybrid seed, developed chiefly as a result of research by the State stations and the Department, in cooperation. Corn-Belt farms grew about 38,066,000 acres of hybrid corn in 1942 or 71.6 percent of the total in that area (12 States), a substantial increase over the 32,090,000 acres (64.7 percent) in 1941.

The contribution of hybrid corn to the national economy, especially in the attainment of production goals, can best be realized in terms of bushels. The 2,270,921,000 bushels of corn in prospect in the 12 Corn-Belt States on September 1, 1942, was about 300,000,000 bushels more than would have been produced with open-pollinated varieties, an increment attributable to the use of hybrid seed.

In 1942, the percentages of the corn acreage planted in hybrids totaled in Iowa 98, Illinois 93, Indiana 91, Ohio 83, Minnesota 80, Wisconsin 76, Missouri 58, Michigan 52, and Nebraska 47 percent. Material increases in the acreage planted to hybrids continued in the Pacific Northwest and in two areas in the Northeastern States. Some advance occurred in West Virginia, Kentucky, and the upper Delta country, but the tardy development of adapted hybrids still has limited the spread of hybrid corn acreage in the Southern States.

Corn improvement and distribution programs of the Stations, Department, and cooperating agencies continued to be potent factors in this phenomenal adoption of hybrid corn in the Corn Belt and elsewhere in the United States. The research and breeding phases have been supplemented by corn performance tests, often State-wide in scope, which compare the newest experimental hybrid combinations with proven regular hybrids and open-pollinated varieties. Although these activities have been most intensive in the Corn Belt and adjacent States, stations in the Mountain, Pacific, Southern, and Eastern States also have programs of some magnitude.

Besides outyielding the open-pollinated corn, superior hybrids are variously characterized by earliness, production of sound corn, resistance to lodging, plant diseases, insects, and other cropping hazards as drought and heat, adaptation to regions, altitudes, and soil fertility. Each of the stations working with the crop usually has a number of promising combinations being subjected to a series of performance tests before being released to growers.

Recently, in addition to the Nation-wide improvement program, other lines of corn research of the stations were also supporting the efforts to meet the national needs as specified in the corn-production goals. The broad scope of the corn research might appropriately be illustrated by some of the activities of the Iowa Corn Research Institute, participated in by research workers of the Iowa Station and the Department of Agriculture.

The research projects fall into 11 groups. One deals with soils and soil management as related to corn production. It is concerned with soil types, fertilizers, amendments, and crop rotations. A second group deals with methods and equipment for seedbed preparation, planting, cultivating, and harvesting, and for the curing and storage of corn, and making of silage. Others include corn production as related to weeds and their eradication; corn production as related to seed, time of planting and adaptation; corn breeding, including the development of pure inbred lines and hybrids and commercially significant varieties; corn genetics; the physiology and development of the corn plant; diseases attacking corn and methods of combating them; insects of corn, their life history, physiology and control; the chemistry and characteristics of corn as a raw product, involving mechanical analysis and separation of corn constituents, and chemical analysis of corn and of the corn plant; industrial utilization of corn; corn products in human and animal nutrition; economic phases of corn production and utilization. Among the latter groups of projects, studies of special current importance deal with the properties of corn-starch, proteins, and sugars, and their utilization and fermentation to supply wartime needs.

Recently, in addition to the Nation-wide improvement program, other lines of corn research of the stations were also supporting the efforts to meet the national needs as specified in the corn-production goals. The broad scope of the corn research might appropriately be illustrated by some of the activities of the Iowa Corn Research Institute, participated in by research workers of the Iowa Station and the Department of Agriculture.

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Wartime Activities

The Office of Experiment Stations and the stations throughout the country quickly reacted to the new problems facing the country during the period of National Defense and after the outbreak of World War II. Effective assistance was rendered to farm families producing Food for Freedom, for research contributes heavily to the abundance and low cost of food in this country, in war as well as in peace. As the needs of our Allies became apparent the research programs of the stations were speeded up and aimed at definite war objectives.

By July 1941 approximately 20 percent of the experiment stations' research projects that had been active under Federal-grant funds during the previous year had been closed out and replaced by new work on problems of immediate significance, or had been revised and redirected to include defense objectives. The prompt and effective aid given by the New Jersey Station to tomato growers of that State which enabled them greatly to increase production is an example. The effective work of the Pennsylvania and other stations in replacing seed of various kinds, formerly imported, with domestic seed is another.

The Puerto Rico University Station undertook a study of the food-canning and processing industries of the Island and all agricultural agencies on the Island were coordinated in an effort to alleviate the food situation in every way possible. The Hawaii Station similarly cooperated with other agencies to promote increased food production. The work of the Colorado, Connecticut, Oklahoma, Florida, Nebraska, and Tennessee Stations also was notable in this line.

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In food dehydration work the New York Cornell, New York State, and California Stations cooperated with the Department. The Wisconsin Station gave great aid to increased production of the cheese required by the British. Vitamin research at the Maryland Station aided in the fulfillment of large British requirements for canned poultry meat and eggs, in 1942, by showing how serious poultry-production losses, traced to deficiencies in vitamins A and E, could be avoided.

The Maryland Station also formulated a low-cost ration for the nearby broiler industry in which byproducts of alcohol manufacture and soybean meal were substituted for milk products, effecting a potential saving of $300,000 a year in feed costs. The Mississippi Station developed a sensitive test for determining the degree of bitterness in milk, caused by the cows' consumption of bitterweed, a serious pasture pest. As a result, much bitter milk could be used in manufacture that would have been otherwise unusable.

The stations did outstanding work on disseminating and putting into practical use the newer knowledge of nutrition. This did much to further the national wartime goal of adequate nutrition for all citizens. Of significant value was the finding of the Alabama Station that sun-drying retains most of the carotene in carrots, sweetpotatoes, and greens, and that winter milk may be maintained at a high level of vitamin A by feeding sweetpotatoes to the cows.

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nitrogen fertilizers. They discovered new methods of making alcohol from cull potatoes or improving the yield of alcohol from molasses. The Delaware Station developed a new pectin which promised relief in the sugar shortage and help in meeting large British demands for pectin. The Wyoming Station shifted some of its current research work in nutrition to speed up work on honey and other sugar substitutes used in cooking.

Emergency research was undertaken by several stations on insecticides and fungicides. Many of them also worked out formulas for substitute spraying materials needed in controlling insect pests. The Puerto Rico Federal Station developed its work on rotenone-bearing plants to produce larger quantities of planting materials for local use and general distribution in the Western Hemisphere.

Two substances obtained by the New Jersey Station from cultures of micro-organisms proved highly destructive to disease-producing organisms and of value in the control of human disease and possibly of war wounds. This research by its soil scientists was then intensified. At the request of a conference on anti-biotic substances called by the National Research Council the station is making extensive isolations of soil and compost micro-organisms, and testing their action against disease-producing bacteria.

Direct aid has been rendered the Military Establishment in many instances, but this is all more or less confidential at present. The OES and the stations have worked to further the program for hemispheric solidarity. The programs of some stations on the study of the essential oils, insecticidal plants, tung oil, spices, and vanilla also assume particular importance.

Furthermore, station directors and staff members have on request undertaken special missions to countries of Latin America. Results of interest to Latin America's techniques which have been developed over a half century of cultural practices and of manufacturing procedures for foods and livestock feeds have been made available as opportunity has been afforded through visits of members of station staffs to these countries to the south of us, and through visits by Latin Americans to the agricultural experiment stations in regions of the United States where conditions and problems are similar.

Cost and Value of Agricultural Research

This account is incomplete, as any account must be of so large a subject. Many more examples could have been included such as, for instance:

The early work of the Department on cattle-tick fever, cooperative with the Texas, Missouri, Mississippi, Louisiana, and other Stations; the cooperative hybrid-breeding programs for wheat and oats with the Wisconsin and Iowa Stations; the grazing and pasture-management studies in cooperation with the Florida and Mississippi Stations; the Sequoia potato developed in cooperation with the North Carolina and the Houma potato in cooperation with the Louisiana Station; the development of bacterial-wilt-resistant Golden Cross Bantam sweet corn in cooperation with the Indiana Station; the development of high-vitamin, high-starch sweetpotatoes in cooperation with the Louisiana Station; the use of maggots (screwworms) in preventing wound infections, developed cooperatively with Texas and other Stations;

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and the fundamental nutrition and calorimetric studies at the Pennsylvania Station which stemmed directly from the original work of Dr. Atwater in the OES itself.

In 1927-28 the total income of the agricultural experiment stations in the continental United States was $14,209,755.04; of this $3,360,000 represented Federal funds. At that time the Department of Agriculture expended $11,300,000 for research, hence the total amount spent for research, Federal and State, was $25,509,755.05. The total estimated capital invested in agricultural production at that time was about $58,500,000,000.

Hence about 43.5 cents per $1,000 of invested capital was spent on research. Industry at that time spent $13 per $1,000 on research. The invested capital as calculated for agriculture does not include processing, transporting, and marketing food.

In this period, 1927-28, our gross income from farm products was $12,250,000,000. Hence the Federal and State Governments combined spent $2 for research per $1,000 of gross income. Again that figure is low. But it was estimated by those who prepared the Survey of Land-Grant Colleges and Universities, Office of Education, Department of the Interior Bulletin No. 9, issued in 1930 (Vol. II, Part VIII on Research), that in 1928 alone this research made contributions of economic value to agriculture to the extent of $842,470,995. In other words each dollar invested in agricultural research brought a return of more than $33, and that estimate is conservative.

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Research Must be Continuous

The continuance of such research is necessary. Continuous expansion of research, with such flexibility of organization that changes of pace and direction are relatively easy in emergencies, there must be. Research must expand in agriculture as it constantly does in industry.

After Pearl Harbor, the immediate action of the State experiment stations in the emergency was to interpret and apply all available and pertinent information to the immediate farming problems of food and fiber production. The next step was to review all current research projects in the light of the national situation and to redirect old investigations or initiate new ones wherever needed for the all-out defense and war effort.

In 1941 the Office of Experiment Stations began especially to encourage the publication of information of special timeliness by the State stations, including accumulations from previous work as well as the sifting out and prompt release of new results from current research. In some cases, authorization was given for the use of Federal-grant funds for short-time projects to take care of the assembling and publishing of research findings pertinent to the Food-for-Freedom program. As a result, the Stations have been issuing a large and increasing volume of information having direct value and application to the war effort and including such matters as the production and processing of food, oil, and fiber crops; nutrition; availability and use of farm labor, equipment, and supplies; preservation of foods; and the locating and servicing of military establishments.

At the end of 1942 more than 3,000 Federal-grant research projects had active status. Of these, approximately 80 percent were rather directly concerned with wartime objectives; the remainder were contributing to the maintenance of sustained agricultural production. In addition, the stations had some 5,500 active projects under non-Federal funds that were helping to meet emergency needs.

SECTION IV

AGRICULTURAL CHEMISTRY

Chemistry was the science applied earliest in the field of agriculture. In 1840 Justus von Liebig's Chemistry in Its Application to Agriculture and Physiology was published, as was noted earlier, and it became tremendously influential. Government aid to agriculture got under way in the United States Patent Office in 1839. One of the half dozen or so major objectives of the Department announced by its first Commissioner, Isaac Newton, was to undertake the chemical investigation of soils, grains, fruits, vegetables, and manures, and to publish the results.

As was indicated in the introductory section, chemistry like microscopy gradually spread over into many Department bureaus, hence not all the notable chemical research of Department workers is covered in this section. That performed by workers in the fields of plant industry, animal industry, dairy industry, forestry, soils, entomology, home economics, and so on will be found discussed in the appropriately designated sections elsewhere.

The first professional employee selected for the new Department was a chemist, Charles M. Wetherill, though a botanist and an entomologist were carried over from the agricultural section of the Patent Office. Wetherill was commissioned on August 21, 1862, but on his arrival in Washington was detailed to special service by President Lincoln, hence he did not start work for the Department until October of that year. His report as chemist submitted January 1, 1863, described investigations on American grapes, sorghum, and sorghum and sugarcane products.

In 1862 Wetherill also published the first technical paper issued by the Department, a Report on the Chemical Analysis of Grapes. Right in the midst of it he entered a plea for more funds! After Wetherill's resignation in October 1863, chemical investigations were initiated by his successor, Henri Erni, upon soils, fertilizers, sugar beets, and fermentation. As early as this, the production of sugar from sugar beets was mentioned as a Department project. Thomas Antisell, Erni's successor, reported on soils, grapes, wines, fertilizing minerals, sugar plants, tanning materials, sweetpotatoes, peanuts, and meat extracts, and he also studied the foods eaten by the American Indians. He served as the Department's chemist for 5 years, and his annual reports included 13 scientific papers on the subjects mentioned.

At this time most wines used in this country were imported and it was considered important that we develop a wine-grape industry of our own. The reports of the early chemists indicated we could grow the grapes and make excellent wines domestically. But many other matters engaged the chemists' attention, for instance projects to utilize the then worse than useless cottonseed for oil.

Ryland T. Brown, who served as chemist in 1871-72 made investigations on cassina, sumac, commercial fertilizers, and the agricultural value of sewage. Under his successor, William McMurtrie, an attempt was made to discontinue the large volume of analytical work on miscellaneous samples submitted to the Department and to confine the work strictly to agricultural matters. McMurtrie initiated work on finding the best localities in this country for growing sugar beets of high sugar content, a project

which Harvey W. Wiley later brought to full fruition.

Peter Collier, who succeeded McMurtrie, probably did more than anyone else to introduce sorghum into the United States as a source of sweetening materials. He was also called upon to analyze cream puffs and coffee suspected of being poisoned, as well as supposedly adulterated tea and bologna sausage. This was about 1878. In addition Collier studied coffee and tea substitutes, baking powders, butter, oleomargarine, and some patent medicines.

The Division of Chemistry Becomes a Bureau

By 1883 serious study was being accorded the chemistry of sugar plants and of butter and its adulterants, the latter as an aid to both the dairy industry and consumers. That year Harvey W. Wiley became chemist of the Department. He began immediately to study food adulterants and he also performed classic work on sugar beets. He was a big man of forceful personality and for a generation he gave great impetus and added importance to the chemical work of the Department.

On July 1, 1901, the Division of Chemistry became a Bureau. It then comprised the following units: A food laboratory under W. D. Bigelow; a road-material laboratory under L. W. Page; a dendro-chemical laboratory for forest products studies under W. H. Krug; a sugar laboratory under G. L. Spencer; an insecticide and water laboratory under J. K. Haywood; a soil laboratory under C. C. Moore; a fertilizer laboratory under E. C. Runyan; and a laboratory for oenological investigations to improve the technique of cider, wine, and vinegar fermentation, under Wm. B. Alwood.

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ahin as a result of Wiley's agitation, was lodged in this Bureau. In 1927 research and regulatory work were separated, however, and the latter became the Food, Drug, and Insecticide, later the Food and Drug Administration. At the same time the Bureau of Soils, which had had an independent career of over 25 years under Milton Whitney, was combined with the Bureau of Chemistry's remaining work, and the Bureau of Chemistry and Soils was thus created.

In 1938 all research work on soils was transferred to the Bureau of Plant Industry while soil reclamation and maintenance work went to the Soil Conservation Service. At this time the Bureau of Agricultural Engineering, which had had an independent existence of some seven years under Samuel H. McCrory was combined with the remaining work of the Bureau of Chemistry and Soils and the new unit was named the Bureau of Agricultural Chemistry and Engineering.

On February 21, 1943, the Division of Protein and Nutrition Research was transferred from this bureau to the newly established Bureau of Human Nutrition and Home Economics. Two days later agricultural engineering research, and research on effluent contaminants, was transferred from it to the new Bureau of Plant Industry, Soils, and Agricultural Engineering, whereupon the Bureau of Agricultural Chemistry and Engineering became the Bureau of Agricultural and Industrial Chemistry, the work of the Regional Research Laboratories being closely integrated with it.

Harvey W. Wiley

It was about 1885 that Wiley began to issue publications which rose to a flood of far-reaching influence. Many of these were veritable

classics and were widely used in educational work. The bulletins which gave methods for the analysis of food, drug, and agricultural products were to be found in every laboratory in the country which engaged in such work. In fact, even after the Food and Drug Act was passed in 1906 and regulatory work began in earnest, there had to be constant research on new methods of analysis for products for which none existed.

Students met the Wiley bulletins early in their college careers and the prestige of Department science was enhanced accordingly. Wiley also issued a bulletin on the manufacture of industrial alcohol from Agricultural commodities in 1910 in the expectation that tax-free denatured alcohol would be made on farms and in rural communities by many small plants as in Europe. All these early publications which issued from the Bureau of Chemistry were of high quality and broad utility.

Wiley's work on food and food adulterants, which appeared in 10 parts, published at intervals between 1887 and 1902, was another Department classic. It was in such great demand that it soon became unobtainable. The work was prepared when cottonseed oil was a common adulterant of butter and lard; when coconut shells, olive seed, rice bran, sawdust, and other foreign substances were used to adulterate spices; when candies abounded in poisonous coloring matter and added metallic substances; when honey was adulterated with glucose or with cane sirup; when chicory was a common adulterant of coffee, while brick, sand, copper, and gypsum appeared in tea; and when poisonous preservatives were used freely in meat and other food products.

It was very largely as a result of the disclosures made by Wiley,

based on studies he had carried on since 1883), that the so-called "pure food law" was passed in 1906. Subsequent consumer benefits of this work have been enormous. It also gave impetus to the examination of foods and drugs for adulterants by other investigators. It formed the technical basis for later evolution of more refined methods of food and drug analysis. This work is more fully discussed in another section.

As a result of publications issued during the first years of this century Dr. Wiley also had a great deal to do with the establishment of the beet sugar industry in this country. By his investigations he determined the localities where sugar beets could be grown commercially. He studied the effects of latitude, altitude, sunshine, rainfall, and many other environmental factors on the growth and composition of the beet, and especially upon its sugar content.

Before Wiley's work, efforts to grow sugar beets for the making of domestic sugar had been sporadic and ill-planned. It remained problematical whether the beet sugar industry could be commercially successful in this country. Wiley's work, broad in scope and systematically carried out over a number of years in widely scattered localities, ended speculation and gave the industry a solid foundation upon which to build. The basic facts established by Wiley and his general conclusions are still valid. Beets are today found to grow best and to have the highest sugar content in the areas he specified. Without this work our prospects of increasing beet sugar production in wartime would be small.

Wiley also studied the possibilities of using the diffusion process, which was successful with sugar beets, for the extraction of sugar from sugar-

cane. He thought that the relatively inefficient milling process used on the latter, which recovered only about three-fourths of the sugar, was a weak point in the industry. Although the diffusion process was not successfully adapted to sugarcane, his researches stimulated great improvement in the milling process and his methods are still used in sugarcane regions.

Wiley had great faith in research. More than 40 years ago he wrote as follows in the yearbook of the Department of Agriculture under the title: "The Relation of Chemistry to the Progress of Agriculture."

"Chemistry has done much to promote the progress of agriculture in the line of chemical technology. Good markets for farm products are essential to progress and prosperity. Many of the raw materials produced upon the farm enter at once into manufacture, and their value on the market largely depends upon the demand for manufacturing purposes. The principal agricultural chemical industries are starch and glucose manufacture, sugar manufacture, wine making, brewing, distilling, tanning, and fertilizer manufacture. In all these industries chemistry plays a leading part."

Thus Wiley distinctly looked forward to great advances in chemical technology. This sort of research has engaged much attention on the part of Department chemists. Examples of their accomplishments in this field will be given later on. Meanwhile an effort will be made to name only a few of the notable chemists who have worked in the Department and to give an indication of their activities.

<u>Notable Workers In Pure Science</u>

Dr. C. L. Alsberg succeeded Dr. Wiley as Chief of the Bureau of Chemistry. Dr. Alsberg was a firm believer in the value of fundamental

chemical research to the agricultural industry. He surrounded himself with men of outstanding ability such as F. B. Power, H. D. Gibbs, R. R. Williams, C. Thom, C. S. Hudson and C. O. Johns. Of these men three, namely F. B. Power, C. Thom (a mycologist), and C. S. Hudson, were subsequently elected to membership in the National Academy of Sciences. Under Alsberg's leadership the Bureau of Chemistry acquired an international reputation as one of the leading scientific research institutions.

When Dr. Frederick Belding Power joined the research staff of the old Bureau of Chemistry he had already acquired an international reputation as an outstanding phytochemist. For 18 years he had been the director of the Wellcome Research Laboratory of London, England. It was while he was connected with that research institution that he proved that the effectiveness of chaulmoogra oil against leprosy was due to two unsaturated cyclic fatty acids present in the oil, namely, chaulmoogric acid and hydnocarpic acid. He also worked out the constitution of these acids.

While at the Bureau of Chemistry, Dr. Power made important contributions on the odorous constituents of various fruits and plants. His outstanding piece of work was perhaps his paper, entitled "The Odorous Constituents of the Cotton Plant" which was published in the Journal of the American Chemical Society in 1925. He demonstrated that the living cotton plant gives off trimethylamine and that it is this substance which in all probability attracts the boll weevil to the cotton plant.

Dr. C. S. Hudson's work at the Bureau of Chemistry may be conveniently divided as follows: (1) Work on the development of methods for the preparation of sugars and sugar derivatives; (2) application of Van't Hoff's

theory of optical superposition to the chemistry of the sugars; (3) work on the theory of mutarotation.

Hudson's outstanding contribution while at the Bureau of Chemistry was the formulation of the generalizations which have since become known as "Hudson's Lactone Rule" and "Hudson's Hydrazide Rule." These rules have been of great value in elucidating the configuration of sugars and sugar derivatives.

The determination of the constitution and the subsequent synthesis of the vitamin B_1 is, of course, the most important contribution made by R. R. Williams. This work had its beginning more than 30 years ago when Williams was connected with the Bureau of Science in the Philippine Islands and was continued by him while he was connected for several years with the Bureau of Chemistry. The work was completed by him many years later after he left the Bureau of Chemistry and joined the research staff of the Bell Telephone Laboratories.

The most important contribution made by Dr. H. D. Gibbs while he was connected with the Bureau of Chemistry was unquestionably his discovery and development of what is known as the catalytic process for the oxidation of naphthalene to phthalic anhydride. This process is now the only one that is used industrially for the preparation of phthalic anhydride, an important intermediate used in the preparations of lacquers, plastics, and dyes. Such important dyes as synthetic indigo, alizarine, and indanthrene are made from phthalic anhydride.

The successor to Dr. Alsberg as Chief of the Bureau of Chemistry was Dr. C. A. Browne. Dr. Browne's reputation as a leading authority in the

broad field of agricultural chemistry well qualified him for leadership of chemical research in the Department of Agriculture. As an authority on the history of chemistry, Dr. Browne infused a broadening influence which was of immense value in developing and expanding the research program of the Bureau. He initiated many research projects which have yielded results of importance to agriculture.

In his chosen field of sugar analysis, Dr. Browne made many contributions involving new and improved methods for the quantitative estimation of sugars and sugar products. His book entitled Physical and Chemical Methods of Sugar Analysis, which he recently revised in cooperation with Dr. F. W. Zerban and published in 1941, after his retirement from the Government service, is recognized the world over as authoritative in the field.

In 1927 Dr. Browne became Chief of the Chemical and Technological Research Unit in the new Bureau of Chemistry and Soils which combined the research work of the former Bureau of Chemistry and that of the former Bureau of Soils on soils and fertilizers. Later he resigned to become Adviser in Chemical Research and devoted all available time to writing on chemical subjects.

Dr. Henry G. Knight was Chief of the Bureau of Chemistry and Soils, later the Bureau of Agricultural Chemistry and Engineering (established in 1938), until his death, July 13, 1942. An important part of Dr. Knight's work was organizing and establishing the four Regional Research Laboratories provided for by the Congress in 1938. These laboratories have been planned

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for the development of industrial uses of farm crops and their research men are now engaged on many problems important in the furtherance of the interests of the United Nations in the second World War.

In May, 1941, Dr. Knight received the medal of the American Institute of Chemists, presented annually "For noteworthy and outstanding service to the science of chemistry or the profession of the Chemist in America." The medal was presented on behalf of the Institute by Vice-President Wallace because of his interest in improving uses of farm crops and because of his years of association with Dr. Knight.

Dr. William Woolford Skinner, who had been with the Bureau of Agricultural Chemistry and Engineering and its predecessors for 38 years, succeeded Dr. Knight as Chief. He had been Associate Chief since 1939 and prior to that had been Assistant Chief since 1935. He had also been Assistant Chief of the Bureau of Chemistry from 1921 to 1927, after which he served as Assistant Chief of the chemical and technological research unit in the newly organized Bureau of Chemistry and Soils. During his long career as a Government chemist, Dr. Skinner has held office in various scientific organizations, including the Association of Official Agricultural Chemists, which he has served as secretary for 20 years.

Dr. Skinner's interest in the industrial utilization of farm crops had much to do with starting the movement for the establishment of the four new Regional Research Laboratories now working on problems of high importance in carrying on the war--such as, for example, improving food dehydration and developing substitutes for rubber. For long he had in mind the desirability of establishing pilot plants to test research results found

promising in laboratory experiments and to carry processes along far enough to determine their industrial practicability. The four Regional Research Laboratories were designed for the inclusion of pilot plants and some of them are already equipped and working on problems of immediate importance.

Facts Accumulated on Proteins and Oils

In approximately 30 years of protein research carried on in the Bureau by Dr. D. Breese Jones and his associates, there has been developed a reservoir of exact information on vegetable proteins unsurpassed anywhere. A part of this information consists of facts regarding the amino acid composition of the proteins of most of the important farm crops. These facts provide means of evaluating the proteins in foods and feeds, but in many cases the analyses were supplemented by actual feeding experiments.

Among the 75 to 100 proteins isolated and studied in this laboratory are those of peanuts, soybeans, corn, wheat, and ten or more varieties of beans. Dr. Jones isolated and determined the nutritive value of the proteins of wheat bran for the first time and the first exact information on the proteins of peanuts came from his laboratory.

In connection with this information, it is important to consider the extensive experiments of Drs. J. Davidson and J. A. LeClerc who showed conclusively that the protein content of wheat may be increased as much as 50 percent by applying inorganic nitrogenous fertilizer at the heading stage of the growing wheat plants.

Fundamental investigations on the constitution of fatty oils of vegetable origin have been going on for nearly 25 years under the direction of Dr. G. S. Jamieson. A large fund of exact information has been accumu-

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lated on oils of domestic and foreign origin. Methods of analysis and investigation of fats and oils have been developed and improved and some attention has been given to study of the composition of vegetable waxes from North and South America.

This information on oils and waxes has proved of basic importance to the industries producing, refining, and using these commodities. The facts accumulated have been of special interest since the war has curtailed importations from Europe, the Orient, Africa, and South America. Dr. Jamieson's book, Vegetable Fats and Oils is recognized as a standard reference work in this field.

Research Stabilizes the Citrus Industry

About 25 or 30 years ago the citrus fruit industry was plagued with marketing troubles. In those days oranges, lemons, and grapefruit went to market only as fresh fruit. The marketing of canned products and byproducts followed the establishment of the Department's citrus byproducts laboratory at Los Angeles in 1911 under the direction of E. M. Chace. This development led to the establishment of other laboratories in Florida and Texas (under H. W. Von Loesecke and J. L. Heid, respectively). As a result of their work citrus fruits now reach consumers in a great variety of forms, and culls and byproducts assume importance.

Not only do our markets take large quantities of canned juice and segments, but the production of citric acid, pectin, lemon oil, and orange oil has grown to a large business. Entirely new outlets have also been opened up. Before the plants for cull disposal were built it cost handlers $1 to $2 a ton to get rid of culls; the existence of byproduct plants, after

research had shown the way, made culls worth $15 a ton. The California citrus byproduct industry has yielded to the growers of that State alone $10,000,000 additional income, and byproducts bring processors a million dollars annually.

Some 300,000 to 400,000 pounds of essential oils, useful for flavoring purposes, are produced annually from citrus culls. The manufacture of pectin from the white part of lemon and orange peels is a considerable industry in itself. It is in common use for making jellies and jams, as a stabilizer in emulsions, and for other industrial purposes. Its wartime use in medicine is of first importance. This entire citrus research program has been highly successful as a basis for auxiliary industries which have tended to stabilize the market for the better grades of fresh citrus fruit.

The United States Citrus Products Laboratory was established at Winter Haven, Florida in 1932. At that time the State had but 12 small citrus canning plants. Peel was a waste which it cost canneries from $25 to $50 a day to have carted away. After 10 years of research there were 38 plants employing 15,000 persons and turning out 14 times as much grapefruit and 11 times as much orange products as 10 years earlier. In 1941-42 some 54 percent of the State's grapefruit and 13 percent of its orange crop went into canned products.

The byproducts of Florida's citrus in that season alone had a value of $1,700,000 for cattle feed, and the making of essential oils and orange-juice concentrate. The research prepared the industry to meet later wartime demands for citrus concentrates, valued for their vitamins, and for

citrus pectins. The press juice, long a nuisance that caused stream pollution, which is a byproduct of making cattle feed from byproduct citrus pulp and peel, is now used, as a result of the Laboratory's researches, for making alcohol for which there is a big wartime demand.

Research on Leather Manufacture

As a result of such experimental work on hides and tanning and uses of leather, it was proved that atmospheric pollution is the determining factor in the deterioration of book-binding leather; that chrome or combination vegetable-chrome-tanned leathers are more resistant to atmospheric pollution than straight vegetable-tanned leathers; and that it is practicable to use waste bark from western hemlock for the manufacture of tanning extracts. In 1942, Ralph W. Frey, in charge of the research on hides, skins, tanning materials, and leather since 1918, was given the W. K. Alsop award for outstanding work in leather manufacture.

Ethylene Gas to Remove Walnut Hulls

The discovery that ethylene gas can be used to remove the hulls of sticktight California walnuts cost the Government but a few thousand dollars. A public patent was granted on the method which now saves California walnut growers several hundred thousand dollars a year. The discoverers were Department scientists who worked with the Ranchito (Calif.) Walnut Growers Association and the California Extension Service. They demonstrated that ethylene gas speeds up the removal of the hulls and prevents the development of a brown color in the walnut kernels which reduces their value.

Ethylene gas now has a variety of uses in treating fruits, vegetables,

and nuts after harvesting. In fact its use on citrus fruits preceded its use on walnuts. It hastens and renders more uniform the ripening of pears. It imparts a pleasing yellow color to the skins of mature, edible oranges which have remained green externally and are therefore less desirable to the eye of the consumer. In this instance the gas merely acts as a developer, bringing out the yellow color which is otherwise masked by other tints.

Research on Naval Stores

Pine gums, rosin, and turpentine are called naval stores, reminiscent of the time when the Navy made dominant use of them. For many years Dr. Fletcher P. Veitch carried on work in this field. The scientific investigations of his laboratory are said to have increased the profits of the naval stores industry by a million dollars a year. The efficiency of the industry has been increased and naval stores products and derivatives have been provided for new uses.

Technological investigations developed improved still settings, a dehydrator for turpentine, methods of controlling turpentine distillation, improved turpentine storage technique, a new steam turpentine still, and better methods of cleaning gum and preventing losses. The research has shown that gum contaminated with iron rust from rusty equipment can lower the quality of rosin as much as three or four grades. The chemists have also brought out improved cups which do not contaminate the gum.

The pine-gum-cleaning process developed by the naval stores research division under F. P. Veitch and his successor, C. F. Speh, cleans the gum or oleoresin before the rosin and turpentine are made. Rosin produced from gum cleaned by this method, on which a public patent was granted, is free

from dirt and other foreign matter, and is much cleaner and brighter than that of a higher, average grade produced from crude, uncleaned gum. The elimination of waste also increases the yield.

Glucenic Acid

A method developed about 1927 for the production of gluconic acid through the mold fermentation of glucose made it possible to produce calcium gluconate at about 50 cents a pound when it had been selling for about $1.50 a pound. Later the Bureau chemists succeeded in developing a still better procedure which cut the cost to about 25 cents a pound. Calcium gluconate is an important medicine for diseases resulting from calcium deficiencies in man and animals. It has likewise been considered for some industrial applications.

Furfural from Agricultural Wastes

The Bureau's work on furfural, and the development by F. B. LaForge, K. P. Monroe, and G. H. Mains of methods for obtaining it from corn cobs, was influential in the general development of commercial processes which have finally resulted in a considerable production of this material, largely from oat hulls. It is used in the purification of rosins, gasoline, and lubricating oils. It is also a basic material in the manufacture of synthetic resins. The result of this research is estimated to be worth $100,000 a year, part of which goes to the farmers who produce the agricultural wastes.

Dye Research Worth Millions

The fast colors of clothing worn by many in recent years are to an important extent the result of research by chemists of the United States

Department of Agriculture. This research developed new technical methods for the production of intermediates for fast and brilliant dyes for cotton. This one piece of research has expanded the cotton market more than a million dollars a year, as well as providing the public with gayly colored wearing apparel that will not fade.

Sweetpotato Starch

The sweetpotato gives promise of becoming an important industrial crop. This is the result of the development by the Bureau of Agricultural Chemistry and Engineering of the United States Department of Agriculture of a process for making high-quality white starch. A growers' cooperative of more than 1,000 members at Laurel, Miss., has produced in one season around 3,000,000 pounds of starch. This new enterprise offers farmers an opportunity to add another profitable cash crop to their present farm program. More recently a commercial concern has started a plant in Louisiana.

Starch had been extracted commercially from sweetpotatoes before, but the product was of a dark and unsatisfactory color and its use was limited. Chemists of the Bureau finally solved the problem of making a clear starch from sweetpotatoes. The new product has been found useful in many industries and for a number of different purposes, including sizing of cloth and paper, adhesives, as laundry starch, and as an ingredient in baker goods and confectionery.

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The Bureau has continued research work, particularly engineering work directed at improving methods and equipment for growing and harvesting sweetpotatoes, and means of handling the crop at the starch plant so that

the plant may be operated the year round. Efforts are also being made to develop methods of manufacturing cattle feed from the residue of the starch plants or from the entire sweetpotato. The State Prison Farm at Atmore, Ala., has built a plant for the manufacture of livestock feed from the entire sweetpotato.

During the 1939 season 2,750,000 pounds of sweetpotato starch were produced as compared with 1,700,000 pounds in 1938 and 500,000 in 1937. The starch is sold principally to southern cotton mills for use in sizing and finishing. Both quality and yield are being improved constantly. Our imports of root starches, which sweetpotato starch in part replaces, were 255,931,676 pounds in 1938. Japan has been making sweetpotato starch for many years. This research thus tends to make us independent of certain imports.

Phenothiazine

The effect of phenothiazine on humans and animals was studied by Floyd De Eds and associates in the Bureau and Stanford Medical School as a result of the proposal to use it as an insecticide. As a result of the studies of its effect on animals, it was found to be one of the most versatile chemicals brought to light in recent years. A public patent was granted to workers in the Bureau of Agricultural Chemistry and Engineering covering the medical use of phenothiazine. Other Department investigators have found that it is useful as a vermifuge for sheep, swine, and horses, and as a fungicide.

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It has proved to be one of the most fruitful in the history of the Department. The drug is more effective against some insects than is nicotine or lead arsenate, and when ground to a fine powder, its usefulness is increased because it cannot then be easily removed from tree foliage by rain. It is toxic to insects, harmless to foliage, and relatively inexpensive.

Sulfur was the starting point of the research for this chemical. Hundreds of organic compounds containing sulfur were developed, tested, and discarded. Weeks grew into months and months into years; the task began to look hopeless, but Dr. Roark and Mr. Smith were not discouraged. The problem not only affected fruit growers but was also of vital concern to the public health. If possible the insects must be killed with some agent that would not be deleterious to human beings. In 1934 phenothiazine, a product of sulfur and diphenylamine proved extremely toxic to mosquito larvae; from then on progress was rapid.

<u>Work on Sugar Plants</u>

Department chemists under the direction of H. S. Paine also have worked out entirely new methods of producing both sorgo sirup and sugarcane sirup. The new methods produce cleaner sirup of higher quality. Malt is used to convert the troublesome sorghum starch into sugar and invertase to prevent the crystallization of cane sugar from sugarcane sirup. The sirups are lighter in color, are of better flavor and odor, keep better, and contain fewer dregs than those made by the unimproved methods.

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Plants are already in operation which use the newer methods. In time the use of these methods will undoubtedly expand the market for sirups of both kinds and thus increase farmer income. In 1942 an experimental project was launched in cooperation with the American Sugar Cane League for the production of up to 10,000 acres of sorgo in the Louisiana cane belt to produce molasses for conversion into industrial alcohol.

A year or so earlier Department chemists saw the possibility of recovering some 6 or 7 million pounds of useful wax from the sugarcane "mud" that results during the process of clarifying cane juice. This wax has both industrial and household uses and the discovery is particularly valuable at this time. The wax occurs as a thin coating on the surface of the cane stalks. The mud has heretofore been thrown away as waste, but when dried it contains from 5 to 17 percent of the valuable wax.

Research in Wartime

Research in the Bureau of Agricultural Chemistry and Engineering was quickly geared to war needs in recent months. This includes investigation of such problems as the utilization of corn starch and dextrose, the effects of storage on corn, starting materials for the manufacture of artificial rubber, new corn-sugar fermentation processes, and modifications of various oils as replacements for those becoming scarce.

Preliminary results of one study indicate that one of the wheat proteins may be valuable in the production of artificial fibers. Successful efforts have been made to use agricultural residues like cornstalks and straw to make plastics and paper pulp, and indirectly for synthetic rubber intermediates. Progress has been made on the preparation of lint cotton

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for use in making smokeless powder, protecting sandbags against rotting, adapting cotton to the manufacture of binder twine, and determining the relative suitability of various kinds of black cotton fabric for obscuring lights.

New methods of dehydrating vegetables, giving products of improved flavor, texture, and packaging quality, have been devised and the quick freezing of fruits and vegetables has been made more effective. Information sheets are issued on the commercial dehydration of important vegetables with blueprints of equipment needed for carrying on the processes. Improvements have been made in preparing and packing fruits for overseas shipment, while flour has been compressed to two-thirds of its original volume to save shipping space without ill effect upon its palatability or nutritive value.

A process has been developed for the quantity production of crystallized sugar from sorghum. Improvements have been made in methods of tung oil extraction. The development of rancidity in stored fats is retarded by using a surrounding atmosphere of carbon dioxide. Methods have been perfected for breaking up soybean oil into a good drying oil and an edible oil, as well as for manufacturing protein plastic from soybean meal. Rubberlike substances have been developed from a constituent of soybean and corn oils.

As usual the investigations urgently undertaken during great emergencies like war build solidly upon the foundation of pure research that has been carried on many years before by workers who had no such emergencies in mind at all. Thus it is always of value to have on hand a stock pile

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The New Regional Research Laboratories

The four Regional Research Laboratories of the former Bureau of Agricultural Chemistry and Engineering, now Agricultural and Industrial Chemistry, that have been getting under way only within the past two years or less, were authorized by the Congress in 1938 in response to a demand for greater industrial utilization of farm commodities. After an extensive survey of crop distribution and industrial developments in the various large areas of the country the Northern Laboratory was located at Peoria, Ill.; the Eastern at Wyndmoor (near Philadelphia), Pa.; the Southern at New Orleans, La.; and the Western at Albany (near San Francisco), Calif.

These four laboratories had barely been equipped when the United States became involved in the war. Although research projects had already been planned, realinements were made so that work of highest importance in the war effort was emphasized.

The Northern Laboratory, which has had assigned to it problems in the industrial utilization of corn, wheat, soybeans, and farm residues such as stalks, straw and hulls, has been investigating specifically the possibilities of making rubber substitutes from different parts of these crops and alcohol for fuel and for use in the manufacture of chemicals, including explosives. Considerable success has attended the effort to make a useful

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rubber substitute from vegetable oils, such as those from soybeans, corn, cottonseed and other crops.

Such a material called Norepol (from the first syllables of northern, regional, and polymer) has been made at the Laboratory. It shows 200 percent stretch and a tensile strength of 600 pounds to the square inch and resistance to oxidation, water, and alcohol. It is being improved and already a number of manufacturers are making the product, some under their own special names.

In addition, the technicians at this Laboratory have developed a method of making butylene glycol through fermentation of grain. This is a step in the making of buna rubber, since butylene glycol can be made into butadiene, well known as a basic material for this synthetic rubber. There are still difficulties in the way of feasible methods for turning the butylene glycol into butadiene. However, the former has been found useful as a commercial solvent and as anti-freeze for automobile radiators.

The Eastern Laboratory undertakes problems on the utilization of milk; white potatoes; vegetables; apples and other fruits; tobacco; animal fats and oils; and hides and tanning materials. Specific matters recently under investigation include the production of nicotinic acid from the nicotine of tobacco, low-sugar jellying pectin, fruit concentrates, plastics and fibers from casein and other proteins, tanning materials to replace those formerly imported, and ways of preventing rancidity in lard and food products containing animal fats.

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have a war application are the development of improvements in the Bureau's process of sweetpotato-starch manufacture, much needed to fill the demand for tropical starches formerly imported from the East Indies; the designing of machines and development of methods for preparing ordinary staple cotton to take the place of cotton linters in the manufacture of smokeless powder; making up and testing binder twines made of combinations of cotton with paper, sisal and other fibers to take the place of manila fiber which is no longer obtainable; and chemical treatments to lengthen the period of usefulness of sandbag fabrics.

At the Western Laboratory research was planned to cover the utilization of fruits, vegetables, poultry products and byproducts, alfalfa, white potatoes and wheat. The war brought to this laboratory an intensified study of the dehydration of food, particularly of vegetables that could be used most effectively in feeding military forces and civilian populations overseas.

Other work important to the success of the war effort includes investigation of problems in the freezing of foods; in the utilization of proteins of wheat and alfalfa and those in feathers, hair, and other animal waste products that might be used in making fibers and plastics; sources of and methods for producing vitamin concentrates needed in the fortification of food; problems in the utilization of pectin in place of gums such as arabic, tragacanth, and karaya, not available because of the war; and new sources of vegetable oils. A satisfactory water-removable ointment base, needed to make ointment for burns, has been made using pectin instead of gum tragacanth.

In the fall of 1942 the Bureau food dehydration technicians, working principally on vegetable dehydration problems at the Western Regional Laboratory, held two dehydration schools for operating personnel of food processing plants to give them the results of recent developments in the Laboratory and elsewhere. One of these schools was held at the Western Laboratory and one at a commercial food factory in Rochester, N.Y.

SECTION V

FRUITS AND VEGETABLES, CEREALS AND FORAGE CROPS

Work with plants of economic value naturally formed an early and important part of Federal agricultural work. What became the Department's propagating garden was established in 1858 by the Commissioner of Patents who had, in 1856, engaged a botanist's services on the recommendation of Joseph Henry, Secretary of the Smithsonian Institution. The Division of Gardens and Grounds was organized under a superintendent soon after the creation of the Department of Agriculture.

A Division of Botany was established in March 1869. It maintained the United States National Herbarium until July 1, 1896, when the herbarium was transferred to the Smithsonian Institution. The Division of Pomology (fruit investigations) was set up in 1886. The Division of Vegetable Physiology and Pathology began as a Section of Mycology in the Division of Botany in 1886; it became a full-fledged division in 1890. Fiber Investigations began in the Division of Statistics in 1889, the Office of Fiber Investigations being established in 1890.

The Division of Agrostology (studies of grasses and forage plants) originated also in the Division of Botany and became independent July 1, 1895. Plant exploration became an officially recognized activity of the Department in 1897 when David Fairchild persuaded Secretary Wilson so to regard it. In his Annual Report for 1900, Secretary Wilson included brief sub-reports, among others,from Divisions of Botany, of Vegetable

Physiology and Pathology, of Pomology, of Agrostology, and of Experimental Gardens and Grounds.

To simplify matters it was decided, in 1901, to establish a Bureau of Plant Industry to coordinate all these stray lines of work. At the same time, by Congressional enactment, the Divisions of Chemistry, of Forestry, and of Soils also became bureaus. The chief of the new Bureau of Plant Industry was B. T. Galloway. He announced that its work would henceforth cover the following fields: Vegetable physiology and pathology, botanical experiments, studies of grasses and forage plants, pomology, domestic tea experiments, foreign seed and plant introduction.

The Bureau was to have under its supervision the experimental gardens and grounds, the Arlington Experimental Farm, and the Congressional seed distribution. It may be remembered that Federal agricultural work really began in the Patent Office with foreign seed and plant introduction and the distribution of seeds.

Under him, Galloway had a veritable galaxy of scientists who were or were to become very well known. The following list is incomplete but may prove useful, no invidious distinctions being intended: A. F. Woods, Erwin F. Smith, Walter T. Swingle, Merton B. Waite, Rodney H. True, William A. Orton, Thomas H. Kearney, Frederick V. Coville, Charles J. Brand, Jared A. Smith, William A. Taylor, Herbert J. Webber, E. V. Wilcox, Lyster H. Dewey, Ernest A. Bessey, Carlton R. Ball, Edgar Brown, Mark A. Carlton, David Griffith, F. Lamson-Scribner, Elmer D. Merrill, Cornelius L. Shear, V. K. Chesnut, A. S. Hitchcock, and David G. Fairchild.

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The first on this list later became Director of Research of the Department and head of the Department's graduate school; the last is the famous plant explorer and the author of The World Was My Garden. Hitchcock's Grasses of the United States is a book of fundamental scientific importance.

On February 23, 1943, agricultural engineering research and the research on chemical weed eradication and effluent contaminants was transferred to this bureau from the Bureau of Agricultural Chemistry and Engineering. The Bureau of Plant Industry then became the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Early Plant Exploration

Between 1836 and 1850, while the agricultural work was still carried on in the Patent Office, such things as methods of combating destructive potato diseases and the varietal improvement of crop plants in order to increase production both received consideration. In due time the science of genetics developed and better varieties were bred not only directly to give better yields, but also to resist plant diseases which greatly lowered yields.

In connection with this work it became necessary to send out plant explorers who returned with new varieties which were either acclimated here, or were used as breeding stock for the development of valuable varieties. But long before agricultural work began in the Patent Office, the State Department had instructed its consuls in foreign parts to send home new varieties of plants and seeds for planting in this country. Naval vessels often brought the stock to this country.

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Introduction of the Washington Navel Orange

These lines of work have long been fundamental to plant research in the Department of Agriculture. Employees often reached out in various ways to secure new varieties of fruits and vegetables. Thus, William Saunders, long Superintendent of the Department's botanical gardens, asked a missionary in Brazil to send him some small trees of the navel orange grown in Bahia. Twelve were sent. Saunders propagated from them. In 1873 he sent two of the young budded plants to Mrs. Eliza (or Luther C.) Tibbets at Riverside, California.

One of these trees died in 1921 but the other (or a shoot from it) even in 1940 was still bearing about four boxes of fruit yearly. It was at this time surrounded by a picket fence and identified by a plate. Most of California's Washington navel orange trees have been derived from it. They have been mistakenly called Washington rather than Brazilian oranges, but the word "citrus" itself is said by linguists to be a mistake on the part of an ancient Greek botanist who mistook an orange tree for a cedar 2,500 years ago, and called its fruit cedar apples.

Some Basic Discoveries Regarding Plant Diseases

Late in the nineteenth and around the beginning of the twentieth century, however, some fundamental research got under way in the Department primarily concerned with plant diseases. Three basic discoveries were made: (1) That bacteria could cause plant diseases, proved and brought to general acceptance by T. J. Burrill (of the University of Illinois), J. C. Arthur (of the New York (Geneva) Agricultural Experiment Station), and

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Erwin F. Smith (of the Department of Agriculture); (2) that insects like honeybees could spread plant diseases, shown by M. B. Waite; (3) that by breeding and selecting individual plants usually could be obtained that were resistant to a specific disease, demonstrated by the pioneer work of William Allen Orton, and carried forward by the research of J. B. Norton and others in the Department.

(Some publications of note by these early workers are: Wilt Disease of Cotton, Watermelon, and Cowpea, by Erwin F. Smith, Division of Vegetable Physiology and Pathology, Bulletin 17 (1899); Data on Stewart's disease of corn by Smith in Proceedings of the American Association for the Advancement of Science (1898); The Cultural Characters of Pseudomonas Hyacinthi, Ps. campestris, Ps. phaseoli, and Ps. Stewarti - Four One-flagellate Yellow Bacteria Parasitic on Plants, by Erwin F. Smith, Division of Vegetable Physiology and Pathology, Bulletin 28, (1901); Wilt Disease of Cotton and Its Control, by W. A. Orton, Office of Experiment Stations, Bulletin 27 (1900); Some Diseases of the Cowpea, by W. A. Orton and Herbert J. Webber, Bureau of Plant Industry, Bulletin 17 (1902).)

Although Thomas Taylor, the Department's microscopist, and others had dabbled in plant diseases previously, dependable work of this sort was inaugurated in the Division of Botany by F. Lamson-Scribner, July 1, 1885. Erwin F. Smith joined him in the work in September 1886, and B. T. Galloway on July 1, 1887. Fundamental research, the value of which is still recognized, was conducted on the diseases of grapes and their control, on peach yellows and rosette, and on a rapidly increasing series of important diseases of economic crop plants of the country as time and increase of staff permitted.

B. T. Galloway assumed charge of the Section in 1888 when Lamson-Scribner resigned to go to Tennessee, and his unit became almost at once the recognized center of phytopathological work in the Western World, and probably was nowhere surpassed. Particular emphasis was laid for some years on life-history studies of economic pathogens and their control by spraying with Bordeaux mixture and other fungicides. This line was not original with Galloway and his associates, but they deserve much of the credit for advancing it and bringing it to general attention.

Insects As Carriers of Plant Diseases

M. B. Waite, who joined the Department in 1888, was assigned to pear blight, a disease then devastating the pear orchards of the eastern United States. It had been demonstrated in 1878 by T. J. Burrill of the University of Illinois that this disease was caused by a bacterium which he named in 1882. This was the first bacterium definitely proved to cause a plant disease.

Waite in his studies of the disease was the first worker to prove that insects could act as vectors of plant diseases when he demonstrated that honeybees actually carried the bacteria from flower to flower. Earlier he had transmitted the disease experimentally by brushing the bacteria into the nectaries of pear blossoms. Then he found the germs on the mouth parts of bees and produced pear blight from them by inoculation. In addition, Waite contributed data on pear pollination and sterility that have become classical.

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Bacterial Plant Diseases

The work of Burrill, Waite, and other investigators, both in this country and abroad, was ignored or ridiculed by outstanding German and English botanists. It was the careful, detailed work of Erwin F. Smith, particularly his famous polemic with Alfred Fischer of Germany, which convinced the skeptics or drove them to cover. Dr. Smith's work on bacterial plant diseases began in 1893, when he laid aside earlier studies of fungus and virus diseases, and by 1901 he had firmly established the science of bacterial plant diseases.

Smith continued his intensive studies of these diseases for many years and his laboratory soon became a noted place of its kind and the mecca of students of the subject from all parts of the world. Extensive publications by himself and associates resulted. The earlier discovery of the crown-gall organism and the resulting studies of the disease in comparison with human cancer represented basic research of great value. The crown-gall organism itself was discovered by C. O. Townsend and Nellie A. Brown working under Dr. Smith's direction.

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same category falls the discovery of E. W. Brandes that Aphis maydis spreads sugarcane mosaic. Many similar discoveries of insect-disease relationships have been made by other Department workers.

Breeding Strains For Plant-Disease Resistance

Of course, it was known before Smith's time that certain fungi could cause plant diseases, but Smith's persistence established the idea that bacteria actually produced many of the diseases previously attributed to fungi. During this time, Orton, then quite young, came to assist Smith. Orton had never seen a cotton plant in his previous New England existence, but he was sent South to devise a way of preventing the wilt which was entirely destroying the crop in large areas. This wilt was not bacterial in origin but was caused by a fungus.

Almost immediately he observed that certain cotton plants failed to contract the disease. He hazarded the guess that this resistence might be hereditary. His Bulletin 27, from the old Division of Vegetable Physiology and Pathology, Wilt Disease of Cotton and Its Control, which appeared in 1900, is a classic in its field. Herein he showed that it was possible to select resistant plants from a population containing disease-resistant cotton parents.

The way was thus paved for further intensive work on cotton wilt, and Orton turned to the production of wilt-resistant cowpeas. Again his basic principle proved sound. Then he produced wilt-resistant watermelons by cross-breeding a palatable, edible melon with a not-so-palatable, wilt-resistant citron. In 2 years he had mapped out the solution, through

selective breeding, for some of the most perplexing problems that still faced Smith, and which he had described in 1898 as the most threatening in the field of plant pathology.

Value of Plant Research

The basic principles worked out or established by Smith, Waite, and Orton, and their Bureau colleagues, have had a later monetary value that is inestimable. Scarcely a fruit, vegetable, or cereal crop exists today which has not suffered at some time from some serious ailment that threatened its annihilation. The breeding of plants resistant to bacterial, fungus, and virus diseases has saved many of these crops. The development of better fungicides has also done its part. Galloway, Waite, Scott, and others did fundamental work on fungicides.

Work of this kind must be continuous. New plant diseases and new races or strains of well-known viruses or fungi often appear. Plant resistance from time to time appears to break down, probably because of mutations in the fungi or viruses attacking it. This work of Department plant scientists ranks with other basic scientific discoveries which established fundamental principles that work successfully in a multitude of specific situations. The toll levied on important crops by plant diseases averages from 5 to 17 percent of their total value.

In an address delivered in December 1936, G. H. Coons, of the Bureau of Plant Industry, made an effort to estimate the annual value to farmers of disease-resistant varieties of the following crops: Corn, wheat, oats, barley, flaxseed, beans, sugarcane, sugar beets, asparagus, cabbage,

cantaloupes, celery, sweet corn, lettuce, peas, spinach, and tomatoes. He arrived at a figure in the neighborhood of from $65,000,000 to $70,000,000. This figure represents the value of disease-resistant varieties to farmers as compared with the money that farmers would have obtained for their crops had ordinary, nonresistant varieties been planted. This annual addition to farm wealth, in large part stemming from research of Department scientists, becomes a still greater contribution to national wealth in the end.

Diseases of Sugar Plants

Thus, in 1926, sugarcane mosaic, a virus disease discovered in 1919, cut the total domestic cane-sugar production to one-fifth of normal, many thousands of acres going unharvested because of this disease and attendant root rots. The cane mills were virtually bankrupt and the industry faced extinction. About the same time, another virus disease, curly top, was causing failure of the sugar-beet crop in the irrigated districts west of the Rocky Mountains. Sugar-beet growing was abandoned in many areas and factories were torn down or moved to new locations, only again to fail. The western beet-sugar industry faced permanent shut-down, involving the loss or idleness of more than $50,000,000 of equipment. These virus diseases were conquered by the introductions of disease-tolerant varieties and the breeding of resistant strains which were able to make a crop in spite of the disease hazard.

Solution of the sugarcane problem involved exploration by E. W. Brandes in the Dutch East Indies to discover improved breeding stocks. Introduction and resettlement in United States of new mosaic-tolerant varieties constituted the first step in restoring the cane industry.

With these tolerant varieties and with the succession of resistant varieties obtained in sugarcane breeding research, the sugarcane industry of the South has been rehabilitated. From $20,000,000 to $25,000,000 was saved the cane industry of Louisiana alone in the decade following 1926. More than simply meeting the threat of disease, the new varieties, and the impetus they have given to other phases of cane culture, have raised the general level of productivity so that cane lands of the South now yield more sugar per acre than ever before in their history.

Breeding research also saved the sugar-beet industry of the West. Selection of the few resistant plants here and there in fields stricken by curly top furnished the foundation material from which Eubanks Carsner and his associates produced in succession U.S. 1, U.S. 34, U.S. 33, and U.S. 12, and now U.S. 22, each more resistant to curly top than its predecessor. Farmers now use these U.S. varieties in confidence that the worst that curly top can do is to reduce the crop 10 to 20 percent; fear of crop failure from the disease is a thing of the past. An annual loss from curly top of from $5,000,000 to $10,000,000 is being prevented in the beet-sugar industry by the new resistant sugar-beet varieties. Without these varieties, it is questionable whether the industry in many parts of the West could have survived the disastrous outbreaks of curly top. But as still other diseases continue to menace the sugar plants, the goal of breeding research is not only to maintain the ground gained but to make still greater advances in safeguarding this crop.

E. W. Brandes, in charge of the Division of Sugar Plant Investigations, has estimated that the improved plant materials issued by his

Division alone have conserved capital and augmented the national wealth by nearly $1,000,000,000. One-half million people who might otherwise have gone on relief owed their means of livelihood to this research, the cost of which was insignificant by comparison.

Furthermore, our dependence on Europe for beet seed, which had lasted more than a century, was ended by workers in this Division. Investigations they undertook, in cooperation with the New Mexico Agricultural Experiment Station, showed that beet seed could be produced efficiently in the United States by a new method differing radically from conventional European procedure which was lavish in the use of hand labor.

By revolutionizing the method, sugar-beet seed was readily produced with short occupancy of the land and effective use of machines. In 1941 more than 7,500,000 pounds of curly-top-resistant sugar-beet seed alone were produced in the United States. The entire domestic requirement of all beet seed, to the amount of 18,000,000 pounds or more annually is now produced in this country. By reason of this research the United States entered the war entirely independent of Europe in this respect.

Preventing Diseases of Vegetables and Cereals.

J. B. Norton's work on asparagus was described in Bureau of Plant Industry Bulletin No. 263, Methods Used in Breeding Asparagus for Rust Resistance. The rust-resistant varieties developed by Norton must have had a monetary value of several million dollars. This work began in 1906 and resulted in the Mary Washington and Martha Washington strains, both highly resistant to asparagus rust. Since 1919 they have replaced practically all other varieties in this country. Norton was among the first

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to approach the problem of breeding for disease resistance from the genetic standpoint.

In the first 44 years of its existence what is now the Division of Fruit and Vegetable Crops and Diseases cost something like $14,000,000. But evidence shows that research carried on therein has paid for this many times over. The breeding of wilt-resistant tomatoes which was begun in this Division by Fred J. Pritchard is an example. As a result, disease-resistant tomatoes introduced by the Division made up one-fourth of this $45,000,000 annual crop by 1933. The return to growers on tomatoes alone was six times the amount spent annually to maintain the Division's entire program of work.

Diseases still take an annual toll of 15 percent of the tomato crop. Until recently the loss was far greater. Breeding work begun several years ago developed improved tomato varieties, including the Marglobe, that are resistant to wilt--the most destructive disease. For some years it has been the most widely grown tomato in the United States and because of its disease-resistant qualities the large tomato-canning industry, which in 1937 had an output valued at $100,000,000, has prospered.

The same thing is true of sweet corn. For years the corn-canning industry was confined to New England and the Atlantic Seaboard because of a destructive bacterial wilt known as Stewart's disease. But Department plant breeders produced a hybrid sweet corn known as Golden Cross Bantam, well adapted to conditions throughout the Corn Belt as well as along the Atlantic Coast. It has proved far more productive than other varieties under adverse conditions, and again the canning industry also benefited.

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It was scientists in this Division also who developed a doubly resistant lettuce, immune to both mildew and blight. Lettuce growing is a $10,000,000 a year industry, hence this achievement alone in a few years yields enough to pay the cost of the Division during its entire existence. For the lettuce industry would have been ruined without its researches.

A few years ago there was developed a potato seedling named the Katahdin, which was highly productive and resistant to mild mosaic. From it other even better strains have been developed. The introduction to the trade of these potato strains alone has more than paid for all the potato investigations ever carried on in the Bureau of Plant Industry.

As a result of investigations carried on in this Division, sweetpotato diseases were reduced as much as 61 percent, enabling growers to produce more with far less work. Between 1918 and 1924, $31,000,000 was lost as a result of sweetpotato diseases, but the loss between 1925 and 1930, a period a year shorter, was only $8,000,000. These savings are attributable to research.

American cabbage became afflicted a few years ago with a disease called the yellows, caused by a soil fungus which never seemed to die out, no matter how long the land lay fallow. Crop growers were deprived of income and many thousands of dollars invested in sauerkraut plants were threatened. The breeding of disease-resistant cabbage solved the problem and saved the industry, returns to growers rising a million a year, to take no account of what sauerkraut manufacturers profited. This work was initiated by L. R. Jones of the Plant Pathology Department at the University

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Conquest of celery mosaic reduced losses of Florida growers from 60 to a mere 6 percent of their crop which is worth $6,000,000 annually. The newer strawberry varieties produced by research are finer and withstand shipping better than those that were grown before.

Enormous contributions made by research on cereal diseases can be given only inadequate treatment here, because of space limitations, in spite of the great economic significance of cereal crops.

In 1935 an epidemic of stem rust damaged the wheat crop in North Dakota alone to the extent of $100,000,000. But Department research in cooperation with the Minnesota Agricultural Experiment Station, developed Thatcher wheat, resistant to a goodly proportion of the known rust strains, and able so far to resist any that have been present in quantity. This single product of research saved in a single State many times the cost of an entire research program covering many projects.

It is impossible to plan a production program intelligently if there are only disease-susceptible strains of cereals like wheat and oats. Rusts and smuts not only decrease yields but also lower the quality of the grain. Gains in quality of resistant varieties are often as important as increased production. A few years ago a large part of the wheat from some areas in the Pacific Northwest was smutty, dockage was heavy, and prices suffered accordingly. These losses were eliminated by research.

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Better Storage, Handling, and Transportation Methods

Extensive work has been carried on in the general field of storage and transportation of fruits and vegetables from the inception of the Bureau. The early history of the refrigeration of fruits and vegetables is outlined in an article by William A. Taylor, then an assistant pomologist, later Chief of the Bureau, in the Department of Agriculture Yearbook for 1900. Other outstanding publications are B.P.I. Bulletin 123 by G. Harold Powell, on the decay of oranges while in transit from California; B.P.I. Bulletin 48 (1903), the Apple in Cold Storage, by Powell and S. F. Fulton; and B.P.I. Bulletin 40 (1903) also by Powell and Fulton, on Cold Storage, with Special Reference to the Pear and Peach.

These early publications really formed the foundation for a tremendous expansion of commercial cold storage and refrigeration in transit. Extensive research has continued uninterrupted with resulting improvements in methods of handling, packaging, and refrigerating in transit. One outstanding single achievement was that of Charles Brooks and associates in developing the use of oil wraps to control or greatly reduce the development of storage scald in apples. This alone extended the practicable cold storage season for apples by 2 or 3 months and saved millions of dollars worth of fruit annually.

The railroads have continually looked to the Bureau for advice and for the testing of new developments in refrigerator-car equipment. The great improvements made in such equipment are based largely on research by Department scientists. More recently the development of portable precooling facilities by the installation of fans in cars has resulted in the

main from the Bureau's investigations. The technique is now used on hundreds of thousands of cars of produce each season.

Other phases of this general problem on which the Department has made noteworthy contributions include treatments to prevent the decay of citrus fruits, particularly the borax wash; methods of degreening citrus fruits to improve their appearance; the establishment of maturity standards for harvesting both citrus and deciduous fruits; methods of effectively removing excess spray residues from fruits; the use of carbon dioxide as a supplement to refrigeration in the transportation of certain fruits; the use of sulfur dioxide in the transportation of grapes; detailed studies of the effect of various temperatures on the ripening of fruits; and investigations on diseases that cause heavy losses in post-harvest operations.

Exploration and Plant Introduction

Exploration to find valuable or disease-resistant plants and their introduction into this country has formed an integral part of much of the research already discussed. The introduction and establishment of entirely new crops, such as the Korean lespedeza, becomes less frequent as the potential possibilities diminish. But the introduction of minor variations and strains of our familiar crops continues unabated with the need for improvement in quality and disease resistance.

David Fairchild, in charge of the Division of Plant Exploration and Introduction from 1906 to 1928, was known throughout the world for the contributions to our agriculture which passed through his hands during that period. In his book, The World was My Garden, the activities of this Division are portrayed through his personal experiences. Since 1898, when

the Department began formally to list its introductions, some 143,000 items have been recorded as introduced for trial.

Today groves of mangoes in Florida, vast grain fields of Russian durum wheat which cover millions of acres, orchards of date palms in California and Arizona and of avocados in California and Florida are but a few of the industries that, as a whole or in part are due to Fairchild and to those who worked with him. The value of these industries exceeds $100,000,000 annually.

Durum wheat, of course, was actually introduced by Russian immigrants to the Dakotas but had not been developed effectively there. That was done by Mark Alfred Carleton, after explorations by himself, N. E. Hansen, Walter T. Swingle, and Carl S. Scofield. Production amounted to only about 60,000 bushels in 1901 when Carleton brought in his introductions and went to work. This built up to 6,000,000 bushels in 1903, and to 50,000,000 in 1906. Acreages were reduced later when hard red spring wheats resistant to rust were developed.

Carleton had become so interested in reports of the investigations made by Hansen, Swingle, and Scofield, that he too had visited Russia, studied the conditions under which the hard wheat grew, and returned with many samples of types he thought might grow well here. He planted the wheat in many localities and began yield and breeding tests. He finally developed strains more resistant to adverse weather than any wheat grown at the time. His work first met with extreme skepticism but it ultimately pushed the Wheat Belt into altogether new regions.

The flour from durum wheat is less white than that from other wheats.

Its gluten content is high. It lends itself admirably to making macaroni and related products. Today the crop still comprises about 6 percent of our total wheat crop, or, say, 50,000,000 to 60,000,000 bushels. Thus a new industry was established in this country based on a plant not hitherto grown here on an important scale. (Cf. The Commercial Status of Durum Wheat, Mark Alfred Carleton and John S. Chamberlain, B.P.I. Bulletin 70, 1904).

Between 1908 and 1913, Thomas H. Kearney of the Department was responsible with others for the introduction into this country of long-staple Egyptian cotton, which had hitherto been imported. It is estimated that by the end of 1940 this industry had been worth more than $120,000,000 to growers. Such cotton is now urgently needed for airplane fabrics and for many other military purposes, as well as in heavy cord truck tires. Past attempts to introduce this cotton had failed because technical control was imperfect, varieties became mixed, and insufficient attention was paid to modifications in cultural practices required to grow long-staple cotton here.

(Important publications in this connection were: Egyptian Cotton in the Southwestern States, by Thomas H. Kearney and William A. Peterson, B.P.I. Bulletin 128 (1908); Experiments with Egyptian Cotton in 1908, by Thomas H. Kearney and William A. Peterson, B.P.I. Circular 29 (1909); Breeding New Types of Egyptian Cotton, by Thomas H. Kearney, B.P.I. Bulletin 200 (1910); Seed Selection of Egyptian Cotton, by Thomas H. Kearney, Department Bulletin 38 (1913); S x P Cotton in Comparison with Pima, by T. H. Kearney and R. H. Peebles, Department Circular 550 (1940).)

After serving it for 50 years, Walter T. Swingle retired from the Bureau of Plant Industry in February 1941. Today millions enjoy the fruits of his research which was chiefly concerned with making successful the domestic culture of date palms and the Smyrna-type fig. When he undertook his investigations Smyrna figs had been introduced in California but would not bear. So Swingle went to Syria and Greece and studied the sex life of the fig where it was native.

He found that certain wasps were bred by the natives and taken to the trees to spread pollen. He sent back wild figs containing the fig wasp from Algeria in 1899; it was then established in California. The wasps first fed on the male fig trees and then fertilized the female blossoms by crawling into them laden with pollen. This was all thought rather doubtful by many scientists of the day but it proved sound. The large Smyrna fig industry in California and Arizona today has resulted from this introduction of the fig wasp.

Swingle also crossed the tangerine and the grapefruit, producing the tangelo. He developed many new and useful varieties of citrus fruits. He likewise established the date industry in the United States. Previously dependent upon imports, this country now grows more than one-fifth of our date consumption. (Cf. The Date Palm and Its Utilization in the Southwestern States, by Walter T. Swingle, B.P.I. Bulletin 53 (1904).)

Sudan grass is an excellent emergency hay and pasture plant that was introduced into the United States in 1909 through the efforts of the late C. V. Piper. From the original 8-ounce packet of seed, the use of this grass has spread until it is now grown in practically every State, the 1941

production producing 92,398,000 pounds of seed alone. In nearly all parts of the country, Sudan grass fills in admirably during periods when drought injury or winter killing lowers the productivity of permanent pastures.

Piper also made vigorous efforts around 1907 to obtain additional varieties of soybean for seed from consuls, missionaries, seedsmen, Government agencies, and foreign explorers. Since 1898 the Department has secured more than 15,000 introductions of soybeans from China, Manchuria, Korea, Java, Sumatra, Siberia, Japan, and India. This has given the United States a wide selection of varieties suitable for many uses and has been an influential factor in increased acreage, production, and utilization of this important crop.

At present more than 150 named varieties are handled by growers and seedsmen, nearly all of which resulted from introductions or selections by Department workers. Before these introductions not more than eight varieties were available, and these were grown only in limited areas. Today about 100 mills engaged in processing soybeans for oil and oil meal, have a crushing capacity of more than 100,000,000 bushels, and more than 200 food and industrial establishments are manufacturing numerous products in whole or in part from the soybean and its products. The value of the crop for all purposes in 1942 was estimated at about $500,000,000.

The introduction of crested wheatgrass, a long-lived perennial bunch grass with marked resistance to drought and cold, should be mentioned. It is native to the cold, dry plains of Russia and Siberia. It was introduced in this country through the Department's efforts in 1898. Other introductions followed, but the grass did not attract much attention till about 1915 when

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it was sown at the United States Northern Great Plains Field Stations at Mandan, No. Dak., and at the Judith Basin Branch Station of the Montana Agricultural Experiment Station at Moccasin.

Soon after 1928, seed of crested wheatgrass began to be produced commercially in Montana; it was first listed by a North Dakota seed dealer in 1929. Now more than 3,000,000 acres of the grass are grown in Montana alone and there are large acreages in neighboring States. At average values for cattle, the crested wheatgrass produces $3 more per acre on native range than do native grass or bromegrass pastures. It is worth several million dollars a year to stockmen of the Northern Plains. It has untold additional value in conserving the soil. Such rangeland is being restored with crested wheatgrass that would otherwise be nonproductive.

Cotton Research

Another type of plant research concerned with increased production was carried on by O. F. Cook, who observed, during a visit to eastern Guatemala in 1902, that the cotton grown by the Indians there was not troubled by the boll weevil. In 1904 Cook was sent to learn the cause of this immunity. An antlike insect was found that protected the cotton plants; Cook was instructed to bring colonies of this insect to Texas, which he did. Weevil-resistant characters were also discovered in native cottons of Central America and southern Mexico; these were introduced into the United States.

Though cotton had been grown and observed for generations, Cook was the first investigator to note that it had two kinds of branches. These developed in relation to conditions of growth encountered by the young plants. Cook saw that the branching habits could be controlled by suitable spacing

of the plants in rows, and this was proved in many experiments. If the plants were left closer in the rows, fruiting branches appeared earlier which considerably shortened the fruiting season and prevented damage by the weevil.

The old method of spacing produced big branches which bore bolls that ripened at different times throughout a long season. Cook's conclusions about spacing to defeat the weevil were contrary to current opinion among growers, planters, and even scientists. But they were slowly accepted and they formed the basis for a fundamental change in cotton growing throughout the world. This helped to make crops profitable where the weevil had formerly destroyed them.

Cook also insisted, along with other cotton workers, that variations in the cotton plant in the South customarily attributed to a so-called "running out" of the seed stock were principally due to seed of different varieties becoming mixed in gins and cross-pollinated in the fields thereafter. He, therefore, began a campaign for one-variety cotton communities and again had hard sledding, but he was finally successful in establishing his idea. The method assumed new significance when Acala cotton was introduced from southern Mexico, improved here, and became well adapted to areas that produce it alone. Pure-seed, one-variety communities rapidly extended the plantings of Acala, not only in California, but elsewhere.

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Variety from Southern Mexico, Department Circular No. 2 (1927).)

Rubber, coffee, cacao, and other tropical crops were studied during the exploration for new types of cotton. The first detailed study of rubber culture in southern Mexico was made by Cook in 1902, resulting in the publication in 1903 of a bulletin on the culture of the Central America rubber tree. New species of rubber trees were discovered. Later experiments by Cook in southern Florida showed that most of the tropical rubber trees could be grown south of Miami, including the Brazilian or Para rubber tree called Hevea, cultivated in the East Indies.

Preventing Diseases of Grasses and Legumes

Comparatively little attention was given to diseases attacking grasses and legumes until rather recently, though they have undoubtedly been responsible for losses amounting to millions of dollars annually. They have both reduced the yields and lowered the nutritive value of forage crops generally. For several years prior to 1925, farmers in some of the best alfalfa districts reported losses of stands within 2 or 3 years where the crop formerly survived a decade or more. In 1925, bacterial wilt, produced by a hitherto unknown organism, was found to be responsible for these losses.

Thereafter the disease spread from the Atlantic to the Pacific and destroyed hundreds of thousands of acres of the crop. In testing alfalfas from all parts of the world for resistance, it was found that only those of Turkistan stood up, but these unfortunately were susceptible to other diseases. However, through selection and hybridization it proved possible to develop a strain resistant to bacterial wilt and satisfactory in other respects. This alfalfa has already been approved for commercial use, and

when sufficient seed is available to meet demands it should save alfalfa growers millions of dollars annually.

The development of red clover strains resistant to anthracnose, and of improved types of sweetclover, constitute important contributions to American agriculture. The introduction and extension of the use of lespedeza are an outstanding accomplishment of recent years. From the first experimental planting of Korean lespedeza made in 1921 this crop has now been extended to about 30,000,000 acres. Demonstration of the value of this crop for areas not well suited to alfalfa, clover, or other common leguminous crops, has meant millions of dollars to farmers.

Value of Pure Research

In some instances it is difficult to estimate the value of a research discovery until some years have passed. Between 1920 and 1928 W. W. Garner and H. A. Allard of the Bureau of Plant Industry were working on what is scientifically called photoperiodism. Their initial discovery was that plants respond to length of day, as it was already known they did to temperature and to intensity of light. After that fundamental discovery, experimental work was carried on to determine the nature of the responses. It was found that the growth, flowering, and fruiting characteristics of many plants, including many of economic importance in our agriculture, vary with variations in the length of the light period to which they were exposed.

"Originally this may have seemed like an interesting botanical fact not of great practical significance," said E. C. Auchter, in an address

at an inter-American agricultural conference in Mexico City.. But many extremely useful things grew out of it. Instead of having to run expensive and lengthy field experiments to determine, for example, what plants will do best in a new locality, scientists can now carry out comparatively inexpensive experiments in a greenhouse. Light and other conditions are controlled to approximate those of the locality in question. If certain varieties of plants prove poorly adapted to the day length and other conditions under study, varieties of high quality and great uniformity can be bred which will usually prove adaptable to the locality.

Again, one of the reasons we can now raise our own beet seed, as mentioned earlier, is that the proper localities in this country to grow the seed were found by determining the rather exacting day-length and temperature requirements for sugar-beet-seed production. In fact, a great deal of time and labor can be saved by growing the beets for seed as a winter annual.

As Dr. Auchter continued, "Onion varieties can be found or bred that will produce bulbs in a short-day region, others in a long-day region; likewise, strawberries that will fruit abundantly in our long-day northern areas, others in the short days of our South. The same thing is true of other agricultural crops. Florists can hasten or delay the flowering of plants simply by controlling the light period in the greenhouse.

"It was found recently that a few minutes of exposure to light near the middle of the dark period gave results similar to those from a full exposure. Grafting a single leaf of an Agate soybean, which blooms readily under long-day conditions, on to a Biloxi soybean, which requires a short

day, enabled the Biloxi also to bloom under long-day conditions. Such facts as these open up fascinating fields for new explorations in plant chemistry and physiology."

(Early publications by W. W. Garner and H. A. Allard appeared in the Journal of Agricultural Research in 1920, 1923, and 1925.)

"The discovery of growth-regulating substances, generally called plant hormones, is another example of basic research that is now giving practical results. We carried this work along quietly for several years, treating various parts of plants--roots, stems, buds, and flowers--with many different substances, some of which had marked effects of great theoretical interest; in some cases the natural behavior of the plant was completely altered.

"In the course of these experiments it was found that apple trees treated with a very dilute hormone solution would hold their fruit without dropping it far beyond the normal period. Hormone spraying of apples is already becoming a standard orchard practice that promises to be of immense value to producers in preventing the dropping of fruit before it has reached good size and color. This single application should save far more than all the money spent on all our hormone research. Yet it was not even dreamed of in the beginning of the research work; in fact, it was simply one of several byproducts of the research job.

"I think we can say confidently that there will be many other practical applications of this work. One of them, already of considerable value, is the use of hormones to stimulate root development in cuttings of plants that ordinarily root with great reluctance. Another, so far tried only

experimentally, is the dusting of blossoms to obtain fruit of better quality with such plants as the tomato."

Waxy corn also merits mention here. As Dr. Auchter said in his address, "In the course of research on the genetics of corn, a plant was developed with a peculiar waxy quality in the starch of the endosperm. It was of no practical use whatever, but because of its theoretical interest it was not discarded but carried along by the breeders. Now this curious corn promises to be of great value as a substitute for tapioca starch, the supplies of which have been cut off by the war."

Other Research of Value and Wartime Activities

Improved dry-land cultural methods developed by scientists in the Department and experiment station have tremendously increased the average yield of winter wheat in arid and semiarid counties of Kansas. Determination of the moisture in soil samples taken at depths of from 4 to 6 feet has been found to save farmers millions of dollars. For from these analyses accurate predictions can be made as to whether the soil should be seeded with crops, and if the deep soil moisture is too low such seedings are not made.

Many other workers and projects could be mentioned. Thus, Allard, who worked on photoperiodism, also did outstanding research on tobacco mosaic. There was N. A. Cobb, world-famous for his exact scientific research on nematodes. Cornelius L. Shear was notable for his work on the sac fungi, carried on for more than 50 years, but only as time permitted.

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Other Research of Value and Routine Activities

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destructive diseases of grape, other small fruits, and cranberry, followed by the development of preventive and control methods. Finally, the discovery that bean seed grown in the West is free from anthracnose has saved farmers of the East and South millions of dollars.

Our plant scientists are constantly finding new varieties of plants to be used for erosion control, developing extra long-staple cottons for specialized wartime uses, making it possible to increase our acreages of certain drug plants, doubling yields of farm crops grown under irrigation by devising new means of culture, rotation, and fertilization, controlling sap stain in lumber, experimenting with plants like guayule, goldenrod, and Russian dandelion, which contain rubber, developing new flax varieties which contain more oil, improving the culture, harvesting, and handling of fiber flax, increasing the oil content of peanuts, and introducing new plants---4,000 in 1942 from Afghanistan, Iran, and India alone.

In June 1942 it was announced that waxy sorghums might be utilized in part as a substitute for imported root starches, formerly used as foods, and in the textile industry for making adhesives. Recent tests by Department scientists had brought out this fact. Waxy sorghum is no new development, of course, as the Chinese have grown such glutinous sorghums for centuries. But in 1921 a Department scientist noted resemblances between the endosperm of waxy sorghum and of the waxy corn that had been introduced from the Orient some years ago.

Later another Bureau investigator tracked down all the important American commercial sorghum varieties that had waxy seed. They have been grown here for sirup, forage, or grain since 1854, in some cases. But they

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are now being widely tested by food manufacturers and makers of adhesives and other starch products. Preliminary studies indicate that a starch can be produced from them which has many of the desirable characteristics of tapioca and other root starches. Commercial processing of waxy sorghum is already under way. So the work ever goes on and on.

The Bureau of Plant Industry estimates that 22 of its research accomplishments bring the American public about a quarter of a billion dollars added income annually. If only 5 percent of its research projects work out practically, and this is far below the actual return, this is calculated to pay $100 for every dollar spent on research. Returns of from 500 to 10,000 percent are not uncommon on basic research. Government research also does much to stimulate research by private enterprise.

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SECTION VI

FORESTRY

The seed from which forest research in the Department of Agriculture may be said to have sprouted was sown in Portland, Me., in August 1873. It took the form of a paper read by Franklin B. Hough of Lowville, N.Y., at a meeting of the American Association for the Advancement of Science, on "The Duty of Governments in the Preservation of Forests." Congress was later memorialized and pressure was put on State legislatures to take action for forest-resource preservation.

It was 3 years, however, before the seed germinated in the form of rider to an appropriation bill passed in August 1876. This provided that a sum of $2,000 be used "by the Commissioner of Agriculture as compensation to some man of approved attainments, who is practically well acquainted with methods of statistical inquiry, and who has evinced an intimate acquaintance with questions relating to the national wants in regard to timber..."

Most of this man's duties concerned the compilation of statistics on forest products, but he was also "to prosecute investigations and inquiries, with the view of ascertaining...the means best adapted to their preservation and renewal, the influence of forests upon climate, and the measures that have been successfully applied in foreign countries, or that may be deemed applicable in this country, for the preservation and restoration or planting of forests..." This act was passed August 15, and before September 1 Dr. Hough was appointed by Commissioner of

Agriculture Frederick Watts to conduct the forestry investigations.

The seedling stage of governmental forest research lasted 10 years, 7 of them under Dr. Hough and 3 under his successor, Nathaniel Eggleston. This was a period of rudimentary development, mainly the collection of information by correspondence--in one instance, at least, a questionnaire was sent to various Army posts in the West for data on local forest conditions. Four reports to Congress by the Department of Agriculture (three by Dr. Hough and one by Mr. Eggleston) covered these activities, which included some work on the part of special agents--one sent abroad in 1881 to study forestry methods, and others dispatched westward in later years to observe forest conditions in various parts of the country and to report on the progress of tree planting in the prairie States.

The Division of Forestry was created in 1881 and attained permanent statutory rank under the Commissioner of Agriculture in June 1886. This marked the growth of forest research to sapling stage. Three months earlier Bernhard E. Fernow had succeeded Mr. Eggleston, and at this time was made Chief of the new Division. The young research organism now put forth many ambitious branches, which included special studies in forest description, forest botany, forest influences, forest products, tree planting, and forest mensuration.

Evidently impressed by the wide activities of the new Division of Forestry, the Congress in 1890, called upon it to investigate rain making, not as a forest influence but by the use of explosives; but as might be expected, foresters did not make much progress nor continue long in this line of research. It was during these years that George B. Sudworth,

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Forest range research began in this period. In 1895 the first appropriation for grass and forage plant investigations was passed by Congress, and this work was taken up by the Division of Agrostology in the following fiscal year. Three years later the Interior Department found itself in difficulties in attempting to formulate grazing rules on the Cascade Range forest reserve, and requested help from the Department of Agriculture. This was given by the appointment of Frederick V. Coville, Chief of the Division of Botany, to make an investigation.

In these early days, as continually in later decades, studies in forest products took a prominent place in the research program. Under Dr. Fernow's administration they covered studies in timber physics and in the properties and uses of wood, including data on railroad ties, heavy structural timbers, wood pulp, charcoal, and naval stores.

The scope of this work is roughly indicated by the 40-odd forestry publications from 1886 to 1898. They covered such diverse research projects as demands of railroads for forest products, designs for timber trestle bridges, osier culture, the characteristics and properties of woods, timber physics, forest mensuration, foreign plant introduction, tree planting, forest influences, and forest conditions in the Rocky Mountains and in Wisconsin. Included also was a report by Dr. Coville on his investigations in the Cascade Mountain Range reserve in Oregon.

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Forest range research began in this period. In 1899 the first appropriation for grass and forage plant investigations was passed by Congress, and this work was taken up by the Division of Agrostology in the following fiscal year. Three years later the Interior Department found itself in difficulties in attempting to formulate grazing rules on the Cascade Range forest reserve, and requested help from the Department of Agriculture. This was given by the appointment of Frederick V. Coville, Chief of the Division of Botany, to make an investigation.

In these early days, as continually in later decades, studies in forest products took a prominent place in the research program. Under Dr. Fernow's administration they covered studies in timber physics and in the properties and uses of wood, including data on railroad ties, heavy structural timbers, wood pulp, charcoal, and naval stores.

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Forest Reserves Come to Agriculture

The sapling stage of forest research may be said to have lasted through the 12 years of Dr. Fernow's administration and for the first 7 years under his successor, Gifford Pinchot, who became head of the Forestry Division in 1898. It was a period of useful activity and growth, but growth definitely limited by the fact that this energetic young forest research organization was without forests to work on. In the Department of the Interior, meanwhile, great reserves of public lands were being established containing millions of acres of forests administered without the benefit of research.

It was natural enough that the Division of Forestry, lacking public forest responsibilities, should devote the benefits of its research to the private forest-land owner, and in 1898 a program with this policy and aim was announced. For the last 7 years of this period forest research was largely dominated by what we now call extension--cooperation, advice, assistance to private owners, and the preparation of working plans for private forests. By 1905, 900,000 acres of private lands were being managed under approved forestry systems, with some prospect that this might be extended to cover 2 million additional acres.

In March 1901 the Division of Forestry became the Bureau of Forestry but was still essentially a research organization and still limited by the fact that the great tracts of Federal forest land, which might be assumed to be the chief field of its endeavor and beneficiary of its accumulating store of scientific knowledge, were being built up in a

separate Department. But 4 years later, a great change took place. By the Act of March 3, 1905, the Bureau of Forestry became (as of July 1, 1905) the Forest Service, and the forest reserves totaling 63,000,000 acres, formerly under the Forestry Division of the General Land Office of the Department of the Interior, were transferred to the Department of Agriculture, together with an administrative organization of some 500 persons.

With this development the research sapling had at last the opportunity to put on wood and, although it had not yet reached maturity, was at least of pole size. In the preceding year President Theodore Roosevelt in his address before an American Forest Congress, called by the American Forestry Association, declared that the object of forestry was not to "lock up" the forests but to "consider how best to combine use with preservation." This policy was echoed in the instructions issued by Secretary of Agriculture James Wilson to Forester Pinchot in which he said that:

"All the resources of forest reserves are for use, and this use must be brought about in a thoroughly prompt businesslike manner under such restrictions only as will insure the permanence of these resources." Further, "In the management of each reserve, local questions will be decided upon local grounds; the dominant independent industry will be considered first, but with as little restriction to minor industries as may be possible... The question will always be decided from the standpoint of the greatest good for the greatest number in the long run." These words are quoted not only because they constitute the dominant

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policy of the Forest Service today as then, but also because that same policy has influenced the development of forest research in the United States from that day.

<u>Research Begins</u>

New responsibilities of administration, of enlarging the forest reserves for the further protection of American forests under the encouragement and with the aid provided by President Roosevelt, were for a time paramount. Research work went on, but mainly under its own momentum and with responsibility for it scattered around in the several administrative divisions of the new Forest Service. Some of the steps taken are, however, noteworthy.

The notion held by some that the results of forestry in European countries could be superimposed upon management of American forests was early exploded. The essential demise of this notion was marked by the setting up of a forest experiment station on the Coconino Plateau in Arizona in 1908. During succeeding years similar stations were established in Colorado, Idaho, Washington, California, and Utah, making one experiment station to each of the administrative forest districts. This was a signal event. It carried out recommendations dating back as far as the meetings of the American Forestry Congress in the 1880's, and echoed later in unpublished memoranda by Gifford Pinchot and Raphael Zon. Another remarkable event of this period was the establishment of the Forest Products Laboratory at Madison, Wisconsin, the importance of which will be discussed later.

Another research undertaking at about this time was the beginning of the ambitious Wagon Wheel Gap experiment in Colorado, in which the Forest Service cooperated with the Weather Bureau. This was the first large-scale experiment in its great outdoor laboratory. The 16 years devoted to it are perhaps justified as much by what they taught the Forest Service and other experimenters regarding the requirements of such studies as by the conclusions drawn from the study itself. It was the first considerable piece of research on the part of the Forest Service in the field of forest influences, a field in which many subsequent forest and range investigations have now been brought together in a Forest Influence Division.

Establishment of an Over-All Branch of Research

Some long-time goals had now been attained but it is doubtful what the achievement might have been in any of these research units had the responsibility for research remained partitioned among the various administrative divisions as it was up to 1915. In that year, however, a Branch of Research was established within the Forest Service organization, uniting all research work and eventually attaining equal status with national forest administration. After nearly 40 years of growth the forest-research seedling had reached its period of greatest development. It had attained the stature which, if we follow the dendriform analogy, would be termed "saw-timber size."

Weather research undertaking at about this time was the beginning of the noteworthy Wagon Wheel Gap experiment in Colorado, in which the Forest Service cooperated with the Weather Bureau. This was the first large-scale experiment in its great outdoor laboratory. The 15 years devoted to it are perhaps justified as much by what they taught the Forest Service and other experimenters regarding the requirements of such studies as by the conclusions drawn from the study itself. It was the first considerable piece of research on the part of the Forest Service in the field of forest influences, a field in which many subsequent forest and range investigations have now been brought together in a Forest Influences Division.

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Laboratory in the National Forests

This gradual growth of forest research has resembled the slow deep rooting of the sapling and progress by definite stages to pole and timber stature. Forest research, unlike some other research units in the Department, had no accidental or incidental beginning as the result of an attempt to solve a pressing problem of the moment. It began rather in response to a public demand for provision to meet a general need of the years to come. This long look forward, providing for years, decades, even a century ahead, has characterized every stage of its development. One of the earliest tasks in the first decades was the development of working plans for the management of timber stands for 40 to 60 years in advance.

Forest research is conducted in a nation-wide laboratory. True, forest-products research has been mainly centralized, blister-rust control has concerned only the white-pine region, and naval-stores investigations are concentrated in the Southern States. But the greater part of forest research spreads through every forest area in the country. Growth and yield studies must be carried on in every timber type. In no one region will seeding and planting experiments suffice to base reforestation under other conditions of soil, topography, and climate. Harvesting practices for eastern forests cannot be prescribed solely on the basis of results from western cutting tests.

Thus most tasks of forest research have too wide a span geographically as well as chronologically to be attributed to any one investigator. More perhaps than in any other line of agricultural research,

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the forester works shoulder to shoulder with his fellow researchers of other days and climes. He continually tests, uses, adapts, or builds upon the work of others, and his triumph is a stepping stone in the path of others who follow.

In other fields of agricultural research a single worker may review the development of racial characteristics through 30 or 40 generations. In forest research no seedling of spruce or oak or fir planted by a Department of Agriculture forester has yet grown to full maturity, and none who could have planted such a tree is here today. The signal individual contributions have been mostly beginnings, adaptations, the perfecting of better methods, or the bringing to fruition of the labors of many others.

Results so attained have contributed mightily to the economic and social development of our country during the past half century. Much of the benefit cannot be estimated in dollars, for it has gone into the preservation and upbuilding of natural resources whose importance to our welfare is inestimable. The only measure of value is the negative one of what it would mean to be without sufficient wood and water and grass and the complex of comforts and necessities that they represent. Where actual values can be guessed at in dollars, the totals are large indeed.

Rescue of an Industry

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the lush southern forests of longleaf pines for turpentine. Only the trees of large diameter were tapped, because of the necessity for "boxing" each tree, or cutting into the butt a rough hollow or "box" to catch the gum flowing down from the wounded "face" above. At the turn of the century, however, the big trees began to be worked out and the prosperity built upon their exploitation seemed about to end.

This was the first of three periods when this industry has faltered and appeared to be doomed, but on each occasion forest research has averted the peril. This time the solution was a simple one—childishly so from our hindsight view, but revolutionary at that time and a rich dividend paid by the tentative and none-too-lavish investments in forest research in the Department of Agriculture.

In 1903 Charles H. Herty brought out his Bureau of Forestry Bulletin on A New Method of Turpentine Orcharding, the fruit of his studies on the adaptation of European turpentining methods to American gum-producing species. By 1905 he was ready to bring to the industry the Practical Results of the Cup and Gutter System of Turpentining (Bureau of Forestry Circular 34). By this new method, the worker, instead of hacking a destructive "box" into the base of the tree, with a blow of the broad-ax affixed a tin trough or gutter just below the face and from this suspended a cup to catch the gum directed into it by the gutter.

This adaptation meant immediate returns to the turpentiner in lower labor cost and less loss of gum, but a far greater ultimate gain in the fact that the old diameter limitation upon his forest crop was removed forever. A cup and gutter could be affixed to any tree, down to the

the last southern forests of longleaf pines for turpentine. Only the trees of large diameter were tapped, because of the necessity for "boxing" each tree, or cutting into the butt a trough below as "box" to catch the gum flowing down from the wounded "face" above. At the turn of the century, however, the big trees began to be worked out and the prosperity built upon their exploitation seemed about to end.

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6-inch sapling. It was as though the Department of Agriculture had presented the turpentine industry with millions of acres of new forests to replace their worked-out stands of old-growth slash and longleaf pine.

Eagerly the industry slashed its way into this new forest, cutting wide and wider streaks in the small trees to make the gum flow faster, running up the faces to 10 feet in 5 or 6 years, and then quickly starting a new or "backface" on the same tree. The unfavorable results of their carelessness alone spoke loudly enough to warn the industry of the approach of another disaster. Fortunately, Department of Agriculture foresters were looking far ahead and this time were able to forestall the crisis before it came in sight.

At the Forest Products Laboratory senior microscopist Eloise Gerry (Department Bulletin 1064, Oleoresin Production, 1922), had been studying the anatomy and physiology of gum production. Her studies led to several conclusions that explained much that had puzzled turpentine operators and more than showed how effectively the industry was killing itself by its present methods of operation. Essentially what she discovered was that the turpentine pine, in the effort it makes through gum-flow to cover its wounds, has a certain rhythm of response.

But operators in their haste to get as many full cups of gum as possible in the shortest time, were missing that rhythm and thereby were definitely discouraging the tree from making its full response. On the other hand, preparatory streaks put in advance of the regular season started the gum response and increased the first season's yield. Half-inch streaks brought as great a flow of gum as wider streaks, and a

face so chipped went up the tree slowly and could be worked nearly twice as long. Too rapid chipping with wide streaks carried the face up beyond the stimulated area—lost the rhythm—got into unproductive tissue.

When tried in the field, Dr. Gerry's findings proved themselves amply. Lenthall Wyman (Technical Bulletin 298, Experiments in Naval Stores, 1932) and later V. L. Harper, James G. Osborne, T. A. Liefeld, and others made additional discoveries vitally important to the industry. Backfaces, they found, must be so placed as to leave a continuous 3-inch strip separating them from front faces. Chipping must be lighter and must be restricted to 9-inch trees or larger. Backfacing must be limited to trees 14 inches and larger.

Defoliation by crown fire retards the yields of gum so much that at least 2 years should intervene between the fire and the next chipping; defoliation by heat from the ground fire is less serious. Air temperatures control gum flow, and a chipping schedule adjusted to seasonal temperature changes brings larger yields for the same labor costs. Even the sharpness of the chipping tools was found to influence materially the flow of gum.

The task now was to persuade the turpentine operators to employ these research results and thereby avert the disaster ahead. A great part of this task was borne by Austin Cary, in his field probably the most effective "research salesman" the Department of Agriculture has ever had. With his subject at his fingers' tips and a keen understanding of the man in the woods he missionaried indefatigably through the South,

teaching men the importance of doing, before it was too late, what they must do, to save themselves and the industry from ruin. Operators knew him well, He was trusted. Many an operator improved his chipping practice because of his confidence in Austin Cary rather than because of any fear of disaster or faith in research. For the time being disaster to the industry was averted.

Today the producers of natural turpentine and rosin are again threatened with eclipse. This time it is the manufacturer of substitutes for naval stores, with his cheaper, big-production methods, who is well on the way to driving the woods producers out of business. And once more farsighted research has come to the rescue. The operator's apparently insurmountable barrier is cost of production.

Producing naval stores from pines needs care and skill that no mechanical robot can supply. Help here was never highly paid; it cannot be got cheaper. Natural products manufactured in the customary small local still are costly because they are wasteful of gum, make poor grades of rosin, and are generally unsatisfactory. Sorely beset by these unyielding conditions, many operators saw no escape from a miserable existence wherein a few might continue precariously in business on the fringes of an industry given over to the synthetic producers. Certainly, without research their chances seemed slim.

One avenue of escape was opened by the Bureau of Agricultural Chemistry and Engineering, now Agricultural and Industrial Chemistry, in promoting the operation of big centralized steam-distillation plants, which offer a good market to the smallest producer. The way out that

forest research offers is a greatly increased production for the same labor cost. It offers two hopeful means to this end.

The first is known as "chemical chipping." As developed by Liefeld, it consists in using a 1/2-inch or larger hack and covering the streak so produced with acid. Essentially this has the effect of making a deeper wound, bringing forth a much greater flow of gum. To obtain the same yield as before, it will be necessary to put on new streaks appreciably less often than before.

The second means of lessening cost by increasing yield is by breeding pines of characteristically high yield. The successful efforts of the Southern Forest Experiment Station in this direction have been greatly advanced by the success of Harold Mitchell of that station in rooting cuttings of mature slash pine--the first time that this has ever been accomplished in any country. As these trees of superior genetical qualities, supplied for naval-stores planting, grow rapidly to producing size, they will supply the operator with two or three times the present yields of gum, and possibly more. These natural increases, combined with the advantages of chemical chipping, bid fair to bring unit costs of gum production to less than half what they are at present.

What this greater yield may mean to the turpentine operators cannot be measured adequately in the millions of dollars of profit that it will bring in. The true benefit is in terms of a failing industry put once more on its feet and given new life and vigor.

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Forest Fire Control

Research came somewhat tardily to the fire fighter's aid. The ruthless sweep of the forest fire, however caused, was too widely and too long regarded as an "act of God." What has been called "the war-club stage" of forest fire control has only in the last 15 or 20 years begun to yield to an era of more enlightened prevention, detection, and suppression based on research. (Mileposts of Progress in Fire Control and Fire Research, by H. T. Gisborne, Journal of Forestry 40: 597-606.)

The first efforts to apply scientific research to fire fighting were directed towards prediction rather than prevention or control and were led by E. A. Beals of the Weather Bureau in his early attempts at fire-weather forecasting. From this correlation of weather with incipient fire danger it was a natural step to the influence of weather conditions on going fires. In the great Douglas-fir forests of the Northwest unmanageable fires often slowed down at dusk and made little if any gains at night, only to blaze up furiously the next day.

This clue was made the subject of careful study by W. B. Osborne, Jr. He found startling differences in humidity in these Douglas-fir forests at different hours of sunlight and dark and noted that these changes were closely associated with the behavior of going fires and the likelihood of fires starting. In this region, at least, the progress of most fires could be roughly charted by the variations in relative humidity. A fire fighter, by whirling a psychrometer or pair of wet-and-dry-bulb thermometers, and reading off the variation as relative humidity, could

gage the rate at which a fire would burn, or the spread of fires that would catch under those conditions.

When Osborne's conclusions were published in 1923, in collaboration with J. V. Hofmann, they were eagerly accepted throughout the West. Here was a simple index of fire danger that anyone could apply. Despite its natural limitation in effectiveness to a few fuels, it was widely adopted at this time. Its principal value, however, was in the vista it opened for further investigations into the influence of fire factors and the possibilities of employing them as indicators of fire danger.

Moisture Content of Forest Fuels

One of the leaders in these investigations was, and still is, Harry T. Gisborne, of the Northern Rocky Mountain Forest and Range Experiment Station. In his inland region, where raged some of the most destructive and costly forest fires in the whole United States, relative humidity of the atmosphere was not so reliable a key to fire danger. Gisborne early turned to the moisture content of the forest fuels as indicator material, first to the decomposed fuel layer, or "duff" on the forest floor. With M. E. Dunlap of the Forest Products Laboratory he perfected the duff hygrometer, a device for measuring easily and quickly the degree of moisture in this material. From this reading, rate of spread of fire in this fuel could be estimated, as well as the chance that man-caused fires would start.

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dangerous fuels, such as dried-out branches or down timber. The most reliable indicator for dead wood was found to be light branchwood, a fuel common wherever there is any tree growth. A satisfactory "hygrometer" for this fuel was simply a number of small sticks 1/2-inch in diameter and of known oven-dry weight, exposed 10 inches above ground at least a half hour before sunset. When these were weighed, moisture content was evident.

But perhaps the most valuable finding by Gisborne was that, for most forest regions, no one instrument reading could suffice as a basis for fire-control administration. He found that moisture, whether in the air or in the fuels, was never the sole determinant of how readily fires would start or how they would spread. Needed, rather, was some means of integrating all the principal factors of season of the year, relative humidity, fuel-moisture content, and wind velocity. Gradually just such an integration was worked out, refined, and proved to be a reliable "burning index." This "BI" is a simple expression of the several conditions to which a forest is exposed, in terms of inflammability.

It has been eagerly applied throughout the country in the form of a great variety of fire-danger meters that are used in many forest types and conditions. The administrator can apply these to fuel-type maps and fire-sighting schedules and ascertain with a high degree of accuracy how many men and what equipment to send to a fire, or to have ready for dispatch upon call. What it has meant in losses prevented and values preserved can only be estimated in terms of reoriented fire-research programs in other regions, in greatly improved fire-control management, and the

stimulus it has provided to seek out the effects of still other factors not yet clearly understood. In making possible a more intelligent handling of fires, a degree of vigilance and preparedness commensurate with the danger faced, and more accurate dispatch of fighting crews and equipment, these research results have contributed greatly towards the saving of timber and avoiding loss of other property and even of life.

Determination of "Allowable Burn"

Investigations in forest-fire control illustrate as clearly as any others the broad scope of any one line of forest research. While these important conclusions were being developed in the Northwest and the Northern Rocky Mountains, S. Brevier Show and E. I. Kotok were engaged on a series of studies in the California forests that have yielded results probably of equal importance to governmental and private owners of forest lands in this and other regions. These studies included an analysis of such fire records as were available for the decade 1911-20, a study of the effect of weather conditions on fires, estimates of latent damage from apparently unimportant ground fires in ponderosa pine forests, and noteworthy studies of the adequacy of current detection and suppression methods.

From these studies and similar work in other regions, it was possible to set up a measure of "allowable burn"--or the area that might be burned each year without serious harm to the sustained yield of timber--as 0.2 percent or 0.1 percent of the total commercial forest area. Such goals, although arbitrary, gave coherence to all suppression effort and to that

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extent, were responsible for much improvement in fire fighting and the consequent saving of millions of dollars of property in this and other regions.

This represents only one of several ways in which forest research has aided in reducing monetary loss from fires and in preserving the forest resource. In their fire-suppression studies, Show and Kotok in California, the late L. G. Hornby in Montana and Idaho, and others, proved the value of greater promptness in detecting fires and in the start and arrival of fire crews, and the importance of establishing goals suitable to different timber types and danger spots. They further proved the necessity, already urged by others, of transportation planning, so that "arrival time" would no longer be a matter of chance for any known fuel type or danger spot.

New Methods of Detecting Forest Fires

Scientific results of all these research projects did much to transform forest fire fighting from desperate battling against great odds to scientific protection of the forest from fire. The next step of Show, and Kotok, and Hornby was to study the essentials of fire detection (Principles of Forest Fire Detection on the National Forests of Northern California, Technical Bulletin 574, 1937); and (Fuel Type Mapping in Region One, Journal of Forestry 33: 67-72). The results completely upset the theories upon which elaborate detection systems had been based.

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Kotok, were responsible for much improvement in fire fighting and the consequent saving of millions of dollars of property in this and other regions.

This represents only one of several ways in which forest research has aided in reducing monetary loss from fires and in preserving the forest resource. In their fire-suppression studies, Show and Kotok in California, the late L. G. Hornby in Montana and Idaho, and others, proved the value of greater promptness in detecting fires and in the start and arrival of fire crews, and the importance of establishing goals suitable to different timber types and danger spots. They further proved the necessity, already urged by others, of transportation planning, so that "arrival time" would no longer be a matter of chance for any known fuel type or danger spot.

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In California, Show and Kotok, assisted by Arthur A. Brown and others, proved that this principle led to much useless duplication, to costly "blind spots," and to great waste of protection effort and expense. They established the importance of distinguishing between mere distance seen and the seen area of greatest danger.

As a result, California's whole detection system was reorganized. The work of Hornby and others in the northern Rocky Mountains brought about a similar revolution in the detection set-up. Again, much chance was eliminated and in its place was a high degree of certainty that every place where fires might spread rapidly would be in direct view of some fire watcher. Again, the forest region and to some extent the whole country were saved great loss.

Meanwhile, up in the Northwest the detection problem was being attacked from a different angle, essentially a very simple one: How far away can a small column of smoke be seen under different atmospheric conditions? This question was addressed in just so many words by the Northwestern National Forest administrative office at Portland, Oregon, to the Pacific Northwest Forest and Range Experiment Station.

It seemed like a simple job--just set a small fire and see how well it can be seen from various lookout points roundabout. The experiment station sent over a couple of men to spend a few weeks working out an answer. That was in 1931, and the research men are still working on the problem. Naturally, great advances have been made and in a measure the problem may be said to be licked; but only in a measure, for there are still unknown elements in the answer, and any one of these may be

the open door to great areas of unexplored knowledge.

Interest in this problem on the part of the national forest administrators grew out of the same sort of effort as that being made in California, to place fire lookouts to the best possible advantage. If it could be assumed that ideal atmospheric conditions were to continue indefinitely, it might be easy to plan a forest lookout system on the model employed in California to cover all the danger spots. But atmospheric conditions are far from ideal much of the time during the fire season, owing to the smoke of going fires and other conditions that produce haze.

It is necessary to supplement the fixed lookout stations by temporary lookouts posted at midpoints within the greatest possible visibility range of the fixed stations. As the haze thickens, more of these must be ordered to their posts; but as the atmosphere clears, they can and should be released for other tasks. But the administrator must know how far a small smoke can be seen in all kinds of atmospheric conditions, and must be able to equip his men to see as far as possible under bad atmospheric conditions, in order to lessen the cost of the detection organization.

Visibility Investigation

Research work in the Northwest was started by Dr. Richard E. McArdle. He found problems that led beyond the realm of the technically trained forester. Considerable material was printed on visibility, but it all concerned objects within doors and questions of interior

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lighting. Never before, apparently, had any serious step been made to discover the visibility of a small column of smoke at a long distance.

At this point Dr. McArdle turned for help to Dr. Knowlton, head of the Physics Department of Reed College, Portland, who assigned George M. Byram, one of his students, to help on the problem. Since then a number of other workers in various regions of the Forest Service have made influential contributions, notably H. D. Bruce of the California station, but it is only fair to say that Byram, who later became a member of the Forest Service research staff, has gone farther and done more than any of the others to find out something about the fundamental aspects of visibility. It is possible that no other agency in the world, nor any other individual now knows more about visibility of small objects than is known in the Forest Service, mainly through the researches of George M. Byram.

Astonishingly enough, this investigation uncovered a great extent of previously unexplored territory. It has to start with such elementary considerations as "How good is the lookout's vision with respect to detection of small smokes at a distance?" And, "Just how hazy is the atmosphere at any given time?" There was no answer to either of these apparently simple questions.

There was no known eye test that could measure the "seeing" quality of a lookout man's eyesight. It was necessary for Byram to invent an eyesight test that would enable the forest administration to detect among applicants for lookout jobs those who had the requisite "eagle" or "hawk" eye vision. This test has been eagerly adopted by the Forest Service. Its value to the Army and Navy in selecting and training plane

watchers and other lookouts may be readily imagined.

A secondary problem was how the lookout man might be equipped best to use his vision. His work is carried on in a glass-enclosed lookout station. When the sunlight is against him, he has much of the difficulty when looking out that we have in looking into a showcase or show window when sunlight shines on it. It therefore became necessary to invent glasses that would remove this glare, and Byram did so.

It was also essential, before conclusions could be reached regarding the visibility of small smokes, to give the lookout man every possible assistance in seeing through the obstructive haze. All lookout men have dreamed for years of some sort of magic device that would enable them to see through haze and yet would make a smoke column stand out in the distance. Byram and McArdle started on that search in the Cascade Mountains of the north Pacific Coast and finished it in the Great Smoky Mountains of the Southeast.

Byram drew on his growing specialized knowledge of optics, continued his observations, and eventually came upon the simple fact that, whereas ordinary light is partially plane-polarized, the light reflected from many types of fire smoke is not polarized. Therefore, a simple polarized filter will enable the observer to see these types of smoke without seeing the haze. A filter based on this principle, called a "haze cutter," was perfected and has been now subjected successfully to 2 years of tests on eastern and western national forests. It has several apparently inevitable limitations in use but even in its present form is of great value to the lookout man.

Effort was being made at the same time to measure visibility, and this was eventually solved by the development of an instrument known as a "haze meter." With this it is possible for the fire-control executive to measure visibility conditions with some degree of accuracy, so that secondary lookout stations in the detection network can be manned when conditions become less favorable for smoke discovery. He can also determine accurately how near to each other permanent and temporary lookout stations should be placed.

Value of This Research to the Armed Forces

Discoveries of such value in fire detection are obviously of considerable value in many ways in the war. The Army and Navy, working on many problems that are similar to those involved in fire detection, can profit from negative as well as positive results, in avoiding time-consuming investigations down blind alleys. Most of all, the fundamental knowledge that has been gained in the research in which Byram has led the way for 6 years will prove of inestimable value in ways unanticipated as yet.

Take a demonstration problem set up by Byram and McArdle on presenting their work to the Army and Navy. It was assumed that an identifying mark might be needed for an airplane or other object that would be of high visibility for close range but invisible at long distances, and correlatively that a mark might be needed that would be indistinct at short distances but easily perceived at long distances. Curves were drawn from the basic visibility formulae

representing the kind of target that would satisfy each of these assumptions. These curves were then translated into definite designs on pieces of cardboard. When they were tested, the long-range target could be seen 12 times as far as the short-range target.

There is evidence that present Army and Navy research regarding visibility can be advanced by several years by the immediate application of what has been learned in this branch of forestry research. What this will mean cannot be estimated in dollars so well as in terms of vital equipment saved from destruction, the prevention of losses of life in our armed forces, and perhaps even greater values in military and naval ends attained that otherwise would have been postponed or made far more costly.

Range Research

The prosperity of the western half of the United States is largely built upon "the miracle of green grass." Range forage builds cattle and sheep and does the job cheaply enough so that good meat is available in greater quantity to more people in this country than it has ever been to comparable industrial nations abroad. That this is still true is chiefly due to range research, which started and today continues on the great western range intermingled with forest land in the national forests.

In the "free-as-air" and "devil-take-the-hindmost" days of western range utilization the belief held firm that here was a truly inexhaustible resource. Did not grass and other forage cover thickly many million

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acres, and did it not renew itself every year? Gradually, however, two facts became evident. Where range was heavily used, the vegetation that came in the spring was often not the same in quality or quantity as that which had been cropped close the summer before. Also, although the range was free, grazing could not always go unrestricted. This latter discovery led to one of the earliest range research projects.

At the close of the last century Secretary Hitchcock of the Department of the Interior found himself poised between the horns of a dilemma. Yielding to demands of valley dwellers in the Black Mesa and San Francisco Mountain Reserves in the Southwest, he had prohibited grazing on the slopes that controlled the watercourses upon which they depended for irrigation. Whereupon he was beset by a storm of protests from the livestock men. Decision one way or the other must rest on definite knowledge of the situation. In short, administration was paralyzed without the benefit of research.

So the Secretary appealed to the Department of Agriculture for technical aid and as a result the first range inspection was made by Forester Pinchot and Frederick V. Coville, and Albert B. Potter who was a representative of the livestock men. The success of the inspection may be gaged by the fact that Mr. Potter became not only a staunch supporter of the range policies of the Forest Service, but was a member of the Forest Service for many years thereafter.

Discovery that the great western range was deteriorating rapidly in quality and density was made first by the technical men. Then their most difficult task was to persuade the livestock owners that

the depletion taking place before their very eyes was a definite loss and not merely the transitory effect of drought years.

In carrying out this task, range research has developed numerous practices designed to insure for the livestock industry the maximum nutritious and palatable forage consonant with a sustained or increasing crop. It would be futile to guess how much this or that result of range research has achieved. Together, and in the measure that each has been accepted by graziers, they have not only rescued the industry from disaster, but have earned for it millions of dollars in increased revenue, and have given it the assurance of perpetual operation.

One of the first results of range research, and one which today is recognized as basic to the greatest single advance in range management in the United States, was the discovery by Arthur W. Sampson (Range Improvement by Deferred and Rotation Grazing, Department Bulletin 34, 1913) as the result of studies begun in 1907, that when the same range area is even moderately grazed for successive years in the growing season, deterioration takes place. Maintenance of forage values, he found, requires that seed of all range plants be allowed to come to maturity every few years. If this is to be accomplished, livestock must be kept off the range until seed ripening at the end of the growing season.

It was found that plants so protected were in no way harmed by grazing after seed ripening, and that the trampling of the livestock at that time served to "plant" the fallen seed. This discovery has entered range-management practice as "deferred and rotation" grazing, whereby grazing is held up each year on successive fractions of the range until seed has

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matured. Thus the whole area is reseeded naturally every 4 or 5 years and persistence of the most palatable grasses—those least likely to reach maturity under grazing—is assured. Deferred grazing has been widely applied not only on national forest and other public ranges, but also on nearly 70 million acres of private ranges through the Agricultural Adjustment Agency.

The inability of most livestock men and even many technical men to recognize range depletion offered a considerable obstacle to progress in early years. Where the most nutritious plants were decimated or killed out by overuse, other less palatable and less nutritious plants increased in density. Thus a range might look well covered with forage though the former forage values had actually been halved. Recognition of the actual condition seldom came before grazing capacity had been greatly reduced or the livestock fell far short of proper weight and condition.

As early as 1917 or 1918, use of the forage crop in the West had reached an intensity that required better control measures. To know what to do, it was essential to recognize accurately the degree and direction of plant succession. Results of the first thoroughgoing studies were published by Arthur W. Sampson in 1919 (Plant Succession in Relation to Range Management, Department Bulletin 791). This work provided a great stimulus to those who were striving to save for the livestock industry the already imperiled range resource.

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work, such other range research would have been less effective or even futile. That such studies were so energetically and thoroughly carried out so early in the history of range research was most fortunate.

In every period of heavy range use, including the present period of war demands, the ability to estimate with certainty what is happening to the forage crop, what chance it has of recuperating, or when at all costs use must give way to range upbuilding, is of crucial importance. Here again is a research achievement impossible to evaluate in dollars and yet undeniably of greatest importance to the past and future welfare of the whole country.

It was James T. Jardine, at present Chief of the Office of Experiment Stations, who in 1907 in eastern Oregon began the studies that led to formulation of practical methods of making range surveys and management plans. This was the third big step forward in the comprehensive effort to retrieve this great national resource from ignorant or heedless exploitation. It showed convincingly the necessity for an estimate, starting with the minute sample plot and arriving at the present total of 175 million acres of western range surveyed, of the actual forage area available and the condition of the vegetal cover upon it.

The basic range-survey and management methods developed by Dr. Jardine, refined and extended by numerous successors at this task up to the present day, are not only standard procedure on the national forests and other public lands but on private land as well. Jardine's crowning effort in range research was his Department Bulletin 790, written with Mark Anderson in 1919: Range Management on the National Forests. It is still the range manager's

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"bible". These methods established by forest-range research have been adopted as fundamental in such agencies as the Agricultural Adjustment Agency, the Soil Conservation Service, Farm Security Administration, and the Division of Grazing and Bureau of Indian Affairs of the Department of the Interior.

As early as 1915, or before, it became apparent that full utilization of the range forest every year could not be considered conservative grazing. It was comparable to working an animal or human each day to the point of exhaustion. Sooner or later the recuperative period would fail to restore the energy balance. Before long, some unforeseen demand would deplete the energy of the individual beyond any power of recuperation and, if the "normal" demand persisted, would result in his total unfitness for labor.

This analogy was followed all too closely on many ranges that were heavily stocked even in "normal" years. So delicate a balance was set up that an unfavorable year was sufficient to upset it. Drought years on the range, like forest fires in the forest, were too long regarded as "acts of God" or strokes of ill luck, against which there was no appeal. Dr. Jardine was one of the first to seek the solution of this difficulty, ably followed by his successor in charge of range research, W. R. Chapline.

From studies extending over many years, it was established that a reserve of untouched forage of the desirable species must remain at the end of the season, if the range was to be maintained in proper condition. Then seasonal inequalities would have no effect on long-time grazing capacity, and even severe droughts could be weathered with relatively small production losses during such years and full recuperation of the forage resource thereafter.

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This original research has been followed up by others, especially by George W. Craddock and Clarence L. Forsling at the Intermountain Forest and Range Experiment Station in Utah (Influence of Weather and Grazing on Sheep Range in Southern Idaho, Technical Bulletin 600 (1938)). It was at length determined that proper stocking must leave 20 to 25 percent of the forage as drought insurance. Further, research demonstrated that such surveys by no means involved corresponding reduction in livestock production from year to year, but rather the reverse.

On conservatively grazed range, calf crops, weight of calves per cow, wool production, and lamb crops all increased materially; cost of supplemental feed per animal was much less where such feed was needed at all; and net profits were correspondingly increased and evidently more secure. Conservative grazing has been amply proved not only to be of direct benefit to the range resource, but to benefit as directly the user in greater and more dependable returns. The possibilities of financial benefit from such research are in the aggregate very great. War demands are being more adequately met wherever these research results have led to conservative grazing.

THE FOREST PRODUCTS LABORATORY

The Forest Products Laboratory was established at Madison, Wis., in 1910. The principal laboratory for forest research will always be in the forest itself, but importance of the founding of this complementary indoor laboratory and its steady growth in usefulness to the Nation can hardly be overestimated. As one writer has said: "The sheer practical value of the thing outweighs any spectacularity of the popular magazine or Sunday

supplement type that can be matched against it... In no other development of the forest conservation idea has there been packed the amount of hard-headed, dollars-and-cents worthwhileness with which, from the beginning, this great experiment has abundantly justified itself." (The Development of Governmental Forest Control in the United States. Jenks Cameron, Brookings Institute, 1928.) Here, research into the physics, chemistry, and technology of wood virtually began in this country.

Since then the Laboratory has advanced these studies and many others, and in so doing has performed a notable service in waking America to the need for thrift in the use of wood and in showing the country the practical road to practicing that thrift. Its gospel has been that forest conservation cannot stop at the millpond, but must be carried on to the way wood is to be used on the construction job, in the furniture factory, in the paper mill, and in every other of the myriad uses to which wood is put. Further than this, the Forest Products Laboratory has developed new uses for wood, new products from wood, even new substances that are hardly recognizable as wood and have radically different qualities from those of wood as such--all direct contributions to the greater well-being of all the people, to a higher living standard in peace, and to greater strength and resourcefulness in war.

Of all those responsible for the past and present achievements of the Forest Products Laboratory, credit for its establishment goes to McGarvey Cline, its first Director. His original proposal for the establishment of a centralized laboratory, backed by the interest of Gifford Pinchot and his own indefatigable labors in pushing the plan, were chiefly responsible for

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putting into effect this reversal of the Forest Service's earlier policy with regard to products research. Up to that time small laboratories had been set up where the materials were; now the materials were brought to the Laboratory. Secondary credit certainly belongs to the University of Wisconsin at Madison, the vision and open-handedness of whose administrators provided the generous cooperation that made possible the establishment of the Laboratory at that institution.

The broad field of the Laboratory's endeavor now includes, among other studies, timber physics, timber mechanics, chemistry and microchemistry of wood, wood pathology, conditioning of wood for use, wood preservation, gluing of wood, painting and finishing of wood, and wood pulp and paper manufacture. At present, all of its activities and personnel are devoted to war work.

It is all but impossible to single out from this broad field of endeavor the greatest achievements or the research workers most deserving of special mention. The three lines of research followed below are selected chiefly because they stem from some of the most simple and elementary problems inherent in the utilization of wood. These are how to condition (dry) wood for use, how to keep wood from swelling and shrinking, and how to fasten wood together.

Conditioning Wood for Use

Although the artificial drying of timbers dates back at least to the time of Hesiod (the eighth century B.C.), the theory of conditioning lumber by the application and control of humidity, heat, and air circulation has developed in this country only in the last 80 years. Until 30 years ago

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it remained little more than theory, then studies were begun by Harry Donald Tiemann, just previous to the establishment of the Forest Products Laboratory at Madison, Wis., in 1910. (History of Artificial Seasoning, Timberman, 27 (8): 184. 1926). When Tiemann's first patent on a kiln-drying process was taken out in 1909, lumber production was at its all-time peak in this country; but practically all of this huge output was conditioned for use by slow, age-hallowed, but uncertain methods of air-drying.

Even a decade after his work was begun, Tiemann acknowledged that practically no one in the lumber industry had any understanding of the principles either of air or kiln drying. (The Theory of Drying and Its Application to the New Humidity Regulated and Recirculating Dry Kiln, Department Bulletin 509, (1917).) Traditional practices were followed, with little or no notion of the reason for them.

As a wet cloth could be hung up on a clothes line and dried, was there any mystery to stacking up wet lumber for air drying? For many years little attention was paid to Tiemann's insistent declaration that lumber conditioning was an entirely different process from the mere evaporation of free water. The physical properties of the wood must be taken into account, and these differed significantly not only from species to species and piece to piece, but often within the piece.

Efforts on the part of the industry to dry-kiln lumber with inadequate equipment and with little or no understanding of drying principles were disastrous. Even 20 years ago, a great quantity of the lumber artificially dried was ruined or at least seriously degraded. Between 1910 and 1926 more than 20 public patents on kiln-drying processes and improvements were taken

out by Tiemann and his coworker Rolf Thelen. But the transition in the industry from extremely wasteful, hit-or-miss drying to scientifically accurate and certain kiln operation lagged sadly behind the opportunity afforded.

Elaborate and complicated tests brought out more and more exact information on the behavior of different kinds and species of wood under various kiln processes and the procedures in the control of humidity, heat, and air movement that were essential to successful drying. But many operators refused to believe that such exactitude of procesudre was any more than white-collar folly. When phenomenal improvements in the product were demonstrated, however, and when run after run of softwoods came out with negligible or no degrade, the industry began to accept the principles of scientific conditioning. Today elaborate schedules for dry-kiln operation are regarded as indispensable in most kiln-drying operations.

The savings possible through the use of improved kilns and carefully-worked-out drying schedules were so remarkable that it was easy to overlook the shortcomings that had not yet been corrected. These appeared mostly in wide flat-sawed plank cut from refractory hardwoods and large boxed-heart timbers. Down in the bottom lands of the Mississippi Valley, at least 25 percent of the hardwood forest could not be utilized profitably because of a similar inadequacy of the improved drying methods. Furthermore, some species had to be dried so slowly, to avoid checking, that kiln-drying operations were far too expensive. To kiln dry 6 by 12-inch Douglas-fir from a green condition to 16-percent dryness required 2 months or more.

This greatly shortened the year or so of air drying required for such timbers, but the cost made kiln drying unpractical.

The basic difficulty was that all lumber and timbers must be dried from the outside in. That is to say, it was impossible to retard the drying of the outer layers of the wood sufficiently to harmonize with the drying of the interior. Consequently stresses were set up which resulted in the checking of the lumber, sometimes to a degree that caused degrading, and always involving some loss. Efforts have been made to overcome this by the application of electric currents to the drying logs, but the results have been uncertain and expensive.

Finally, after 3 years of intensive work an investigator at the Laboratory, W. Karl Loughborough, evolved a new method of seasoning that has satisfactorily solved the difficulty. (Chemical Seasoning of Wood, Southern Lumberman, V. 153, No. 1931, p.42. 1936.) By an analysis of what takes place in the process of drying lumber, he sought and finally brought about in a relatively simple and inexpensive fashion the conditions that would cause an outward rather than an inward drying process.

To put it very simply, Loughborough noted the accepted fact that moisture in a piece of wood moves from situations of higher vapor pressure to those of lower vapor pressure. It might be said that the water runs down the hill of vapor pressure. It is only necessary, therefore, to find some way of lowering the vapor pressure in the outer layers of the wood. It is known that when common salt or any of several other chemicals such as mono-ammonium phosphate, zinc acetate, invert sugar, borax, or baking soda is dissolved in water, the vapor pressure of the solution is

considerably lower than that of the water alone.

Accordingly, planks are soaked in such a solution long enough for it to penetrate the outer layers. When the planks are later dry-kilned, the chemical solution in the outer layers, by lowering the vapor pressure, causes the inner moisture to make its way outward, where it is eventually evaporated by the movement of heat and air within the kiln. As a matter of fact, the interior starts drying even in the chemical bath, so that the 7 or 8 days spent in the solution represent no loss of time in the whole conditioning process.

Furthermore, the vapor pressure of the salt-saturated outer layers, amounting to 75 percent of that of the interior of the wood, is in equilibrium with a 75 percent relative humidity outside the wood. This makes it possible, in kiln drying, for the humidity to be brought down to 75 percent. This lower humidity cuts the drying period down by half, in some instances.

A striking example of what this means is given by green swamp oak. A plank of this species must ordinarily be dried in a relative humidity not lower than 92 percent if bad surface checking is to be avoided, with corresponding retardation of the drying process. Chemically treated, green swamp oak, however, can be dried at 75-percent relative humidity like any other treated wood, with a considerably increased drying rate and much less seasoning degrade. The same thing is true with other species. The aforementioned 6- by 12-inch Douglas-fir timber when chemically treated can be dried to 15-percent moisture content in 34 days, as opposed to 60 or more days by the ordinary process, with practically no checking.

The importance to the lumber industry of this discovery is emphasized. Kiln-drying and air-drying losses have long been considered inevitable in hardwoods and in large timbers of numerous woods, but the losses due to this inadequacy of treatment have been expensive. They ran into millions of dollars and billions of board feet of lumber lost. Today, when wood is of first importance as a war and a replacement material, and is itself becoming scarce, the overcoming of much if not all degrade in treatment of the difficult woods is of incalculable importance and value. These refinements in the conditioning of wood form an excellent example, too, of the fact that forest research is usually a composite achievement.

Control of Swelling and Shrinkage

Another fundamental problem in the utilization of wood products has been the tendency of woods to take up and give out moisture and to swell or shrink in so doing. This quality has made wood unsuitable for many uses. If this tendency could be overcome, the possibilities in the substitution of wood for other materials, where except for this fault it might well be superior, would be greatly increased. Early efforts to solve this problem proved unsuccessful. It became clear that the only answer would be to treat the wood with some material that would combine with the structure of the wood itself and render it impervious to water.

A remarkable answer to the problem was at length achieved by the help of the researches of Alfred J. Stamm into the physical and colloid chemistry of wood. Investigating the ultra-microscopic structure of wood, he discovered that the hydroscopic qualities that were chiefly responsible for the shrinking and swelling difficulties in the use of wood, inhered

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therein. Consequently, efforts to cure these characteristics by forcing water-resistant materials into the larger openings in the wood were bound to get nowhere. The only solution seemed to be to get into the wood structure some substance that would solidify within the microscopic structure.

Exactly this result was finally achieved with the help of synthetic resins. It was found that when the wood was impregnated with a water-soluble mix of resin-forming chemicals, so that these materials entered the cell-wall structure of the wood, it was possible by subjecting the wood to heat to bring about a curing of the deposited resins. Thus the cell-wall structure was entirely filled and given a high anti-moisture, antishrink quality. Wood so impregnated and treated is now known as "Impreg." This treatment markedly improved some of the mechanical properties of the wood, particularly hardness and compression perpendicular to the grain.

The development of "Impreg" at the Forest Products Laboratory led to further development. It was found that the presence of the resin within the cell walls of the wood in addition made it possible to compress the wood under a lower pressure than that required for untreated wood. Because of this, it was possible to compress the uncured resin-treated wood with heat in such a way that the infused resin was bonded with the wood.

Thus was produced a substance of greatly increased density, hardness, and resistance to the moisture, shrinking, and swelling, and with its properties generally so changed and improved that it might almost be considered a new substance neither wood nor metal having uses perhaps yet not

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guessed. Certainly, when this product is built up into thick sections of plywood, in which the hard self-glossed layers, which are known as "Compreg," are added to uncompressed cores of Impreg, there appear to be numerous possibilities in its use for ground-test and flight propellers, airplane landing-wheels, electrical control housing for torpedo boats, special deck planking, airplane semistructural skin surface parts, and other airplane fittings.

Fastening Wood Together

The Laboratory work in assembling or fastening wood has followed three main lines—container tests, perfection of metal connectors, and gluing of wood. The container work, advanced long before the war (Design Factors Affecting the Strength and Rigidity of Wooden Crates, Circular 236. (1932); and Principles of Box and Crate Construction, Technical Bulletin, 171, 1930), has been invaluable in connection with the war.

In our present overseas operations hundreds of thousands of different articles must be boxed or crated for shipment by rail, convoy, or plane. Not only must these articles be adequately protected from shock, sea air, heat, cold, and other contingencies, but no crate or box must weigh an ounce more or take up a square foot more of space than is absolutely essential for such protection. Every article supplied to our own men and allies abroad, from a delicate instrument for airplane navigation to a mammoth tank, from powdered eggs to "block busters," has made its separate demand on the greatly enlarged container division of the Laboratory.

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times even greater reductions in bulk of required containers. Heavy tanks moved by rail were lifting the flat cars to which they were fastened off the rails until the Laboratory provided an equally secure but less rigid method of holding them down. In every shipment made, the years of research in box and crate construction by J. A. Newlin, Thorwald A. Carlson, the late C. A. Plaskett, and others of the Forest Products Laboratory have contributed specifically and tellingly to the war effort of this country and its allies.

Many examples could be cited of improvements made in containers, of which hundreds of thousands have been used during this war and must continue to be used, each single container contributing its savings in space, weight, cost, and greater serviceability to a huge aggregate of shipping space gained, war funds economized, and an earlier and less costly victory. One minor example is a redesigned container for the shipment of bombs. Cheaper, less-in-demand aspen was used instead of white pine; the amount of lumber used in and the space required for the container were materially reduced, with corresponding considerable reductions in weight. The redesigned container had, in addition, appreciably greater strength than the original.

Equally interesting work done in recent years in testing and perfecting metal connectors for wood joints has also earned a place in the present emergency, although not so spectacular as that of container research. Joints and fastenings are the weakest part of any timber structure, and this weakness has heretofore precluded the substitution of wood for steel in much construction work. Metal connectors are devices used in conjunction with

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bolts to greatly increase joint efficiency by preventing "shear," or side-slipping of the joined surfaces. The types perfected either fit securely into precut grooves or bored recesses, or are pressed into the wood between the members to be joined.

Timber connectors have effected substantial savings in steel and iron, measured by 1,500,000,000 board feet of timber used in the efficient construction of many thousands of structures all over the United States, including bridges, hangars, factories, and ship lofts. Timber connectors used with lumber have already diverted up to a half million tons of steel into more direct war operations where only steel will serve.

Gluing of wood dates back to the beginnings of the cabinet maker's art. Wilkinson in his Manners and Customs of the Ancient Egyptians shows a spirited Egyptian mural dating from 1500 B. C., in which various stages of veneer work are shown including a glue-pot on the fire. Forest products research in wood glues had little opportunity for the discovery of new products, but it has had a useful history in developing and establishing modern gluing techniques.

Perhaps no single factor has been responsible for more significant advances in the field of modern wood construction. The research has consisted in seemingly endless experiments at the Forest Products Laboratory, in which the several types of glue and many combinations of these types have been applied to all the commercial wood species to test serviceableness, strength, durability, water resistance, tendency to stain, effect on tools, and other special requirements. From this laborious gluing and testing of hundreds of thousands of joints, a manual of gluing techniques

was evolved by T. R. Truax (The Gluing of Wood, Department Bulletin 1500 (1929)), under whose direction gluing studies have been carried on at the Laboratory for many years.

In the course of time there have been considerable changes in the requirements for these glues. Aircraft manufacture has set up new demands. Animal glue is employed in the manufacture of wooden propellers, partly because of its relatively slight dulling effect on tools. Casein glues, which are mixed and applied cold, are used chiefly for assembly operations where the application of high temperatures is difficult or impossible. Blood-albumen glues, which must be applied with hot pressing to develop full strength and moisture resistance, are employed in the flat plywood used in aircraft. At present, the demands for use of glue in many types of plywood and laminated wood construction, or built up timbers, have transcended requirements for most other uses.

One of the most significant developments from the work done in glues is laminated wood construction. (The Glued Laminated Wooden Arch, Technical Bulletin 691 (1939).) The building up of laminated timbers, generally with the aid of casein glues, has resulted in the supplying of structural material practically as durable as solid beams, but with strength qualities considerably in excess of solid members of the same size. The glued laminated wooden arch, developed to its present degree of efficiency by T. R. C. Wilson of the laboratory has greater strength and efficiency and a better appearance than can be obtained with other wood types and is a remarkably effective substitute for metal or timbered arches. An added advantage is that up to 60 percent of low-grade woods can be used without

impairing strength or durability.

Such construction is well known abroad, but the techniques developed at the Laboratory have adapted European techniques to the requirements of such construction in this country. The first building in the United States constructed with these arches was erected in Madison, Wis., in 1935. Since then the arches have been employed in hundreds of large structures, including gymnasiums, community buildings, churches, theaters, and club houses, and their use can well be expected to expand as their possibilities become more widely known. Laminated wooden arches have been built to span 150 feet between buttressed walls. This construction is well adapted to farm buildings, especially for barn rafters, and hundreds of such barns have been erected.

Up to a decade ago the principal available glues were starch, animal (bone and hide), fish, casein, and blood, the last two being water resistant. The great progress made with these types has been somewhat overshadowed in the last decade by the development of synthetic resin glues, of which the best known are the phenol-formaldehyde and the ureaformaldehyde types. These glues render the joints of plywood layers with which they are used practically impervious to water and to heat. They have proved to be superior to other types of glue in several ways; but it is characteristic of gluing research that nearly every type of glue has its preferred uses and meets certain requirements better than any other.

For this reason, gluing research has not been a progression from one discovery to another so much as a continuous effort to develop full acquaintance with the possibilities of each type of glue, and to express

these possibilities through carefully worked-out and tested techniques. The development of synthetic resin glues has widened to a considerable extent the field of wood utilization but without eliminating the usefulness of other types of glue for the processes and products for which they are best suited.

Other Lines of Research

At the Forest Products Laboratory and throughout the Forest Service, other interesting histories could be produced of equally significant lines of research, each of them opening some vista of broader or better utilization of forest products. They include studies of the pulping possibilities of southern pines, carried on indefatigably for many years under the direction of the late Henry E. Surface and his successors. The culmination of these studies, resulting in craft and fiberboard processes adopted by numerous new pulp mills in the South, was providential in its timeliness. Defense and war demands for fiber containers for lend-lease shipments have set southern pulp mills working to capacity. Today southern pines, not spruce and hemlock, are the leading pulp woods in the United States.

Other histories could be written of such studies as those that brought forth the newly discovered plastic wood and the different but equally significant wood plastics. Wood plastics have developed out of a recent discovery by which a wood component, millions of tons of which were formerly disposed of as waste in the process of making pulps, has been found to yield a number of compounds new to the chemical world but with promising possibilities for the future.

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Less alluring but far more important to the lumber industry and users

to all wood technology is the patient, persistent, painstaking work of John A. Newlin and his co-workers in studies of the mechanics of wood. Thousands upon thousands of tests were made of 164 species of commercial woods to determine breaking point, elasticity, and working strength under bending stress, resistance to crushing, resistance to compression parallel to grain and across grain, tensile strength, shearing strength, hardness, susceptibility to splitting, and so on. From these data came reliable tables of strength and related properties that are used to greater or less degree in all structural and industrial uses of wood. (Strength and Related Properties of Woods Grown in the United States, by L. J. Markwardt and T. R. C. Wilson, Technical Bulletin 479, (1935).)

Possibilities of breeding trees to grow the kind of products that are needed have already been touched on in connection with naval-stores research. But we are learning also to grow the kind of timber we want in other species, such as dense or soft pine, especially tough ash and hickory. Such discoveries are completing the circle begun when forest products research was set up as an outgrowth of forest management research.

In forest economics, in addition to the great Nation-wide survey of the whole forest resource, whereby we are able to inventory the remaining stands, the growing stock, and the actual degree to which the stock is being reduced by use, extremely valuable contributions to the common welfare have been made in determining the economic rotation of the forest stands, or the size of trees to be cut and the way in which to harvest most economically the forest growth in timber stands and on farms.

Basic to our whole forest resource is the forest-soil resource, and

it has been the task of those engaged in forest influences research to uncover the harm done to forest soils by unwise utilization of timber or forest range, and to find the ways in which such harm can be prevented. Such research is not conspicuous, and there are few if any opportunities for any individual scientist to make a name for himself by revolutionary discoveries; yet without this basic research the greater part of the forest and range resources would be endangered. Wood, water, and grass are now the sinews of war, and so far as possible, without needlessly jeopardizing valuable research projects begun in peacetime and already substantially completed, the whole forest and range research organization is devoted unitedly to the solution of problems intimately related to wartime needs.

FOREST PATHOLOGY

Studies of the diseases of forest trees had taken place mainly in Europe before 1900, and were observational and qualitative rather than experimental or quantitative. The Bureau of Plant Industry through its Mississippi Valley Laboratory at St. Louis, under the leadership of Herman von Schrenk, initiated further studies, the results of which included a general bulletin on the diseases of hardwoods, which was immediately recognized as a standard work. In 1907 the headquarters for this work was moved to Washington, D.C., and a special division was established to work entirely in forest pathology, under Haven Metcalf.

The major line of activity at first was necessarily concerned with the introduced epidemics of chestnut blight and white-pine blister rust. It proved to be impossible to control the chestnut blight and the ordinary

methods of plant disease control are impracticable in most forest disease work, but a variety of helpful results were secured. Prompt demonstration that these two major diseases had been introduced on nursery stock and that similar introductions could not be sufficiently safeguarded by the State inspection system then in force, led to the passage of the Federal Plant Quarantine Act in 1912, as a basis for the protective activities of the Federal Horticultural Board, the functions of which are now carried by the Bureau of Entomology and Plant Quarantine.

Chestnut Blight

Technical accomplishments in the case of the chestnut blight included the conclusive demonstration that the disease had come from Asia, for which it was necessary to overcome the insistence of the mycologists in some of the universities that the causal fungus was one of our native organisms. The rate of spread of the disease was forecast, and assistance was given to the Forest Service and to private land owners in utilizing their timber to the best advantage before the disease rendered it worthless.

Resistant chestnut species were introduced from Asia and tested in direct planting, as well as hybridizing with the susceptible American chestnut. Trees with resistance to the disease, valuable nuts, and high tannin content have been secured. The breeding of forest trees, of course, requires a much longer period than in the case of short-lived plants and it is too early to say to what extent the new varieties can replace the original chestnut.

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White Pine Blister Rust

In the case of white-pine blister rust the European evidence that these required currants and gooseberries as an alternate host was confirmed. Practicability of control by separation of the host plants was demonstrated, and a scientific basis was supplied for the Nation-wide control campaign that has saved the eastern white pine and is now being carried on vigorously in the western white-pine and sugar-pine regions.

White pines are unique in the quality of their wood and their perpetuation in many regions is essential or profitable silviculture. The stumpage value of the three principal white-pine species is estimated by the Forest Service at about $300,000,000. In areas with prevalent alternate hosts where there has been no control effort all three of the important white pines are being killed by the disease. It is especially destructive to the young growth on which depends the commercial maintenance of the trees in our forests.

Dutch Elm Disease

The Dutch elm disease was found to have reached this country in burl elm logs from Europe and was distributed around ports of entry, along railroads, and around veneer factories where the logs were used. An extensive control campaign by the Bureau of Entomology and Plant Quarantine is under way.

Additional epidemics have since reached this country, attacking the minor species persimmon, mimosa, and Monterey cypress, and the major species American elm. In all of these it is too early to predict the outcome but, all four species, the development of resistant varieties has been undertaken.

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The same thing is true for the eastern white pine, the work being in cooperation with Wisconsin and New York State institutions, and there is reason to expect a successful outcome.

Heart Rot

Beginning in 1910 quantitative studies were instituted on the heart rots of standing timber. These for western virgin stands and for balsam fir in the East have supplied a basis for timing logging operations to get the most timber consistent with avoidance of the heavy deterioration that accompanies overmaturity. By supplying methods of distinguishing high-risk and low-risk trees they have also given a basis for selective logging and for the thinning, pruning, and other improvement practices in young stands.

In stands of sprout oak, for example, it was found that sprouts which originated high on the parent stump ordinarily become infected from the old stump when very young, whereas sprouts that originated at ground level were nearly as safe from decay as trees of seedling origin. This one finding opened the way for intelligent handling of the large and increasing areas in the Eastern States in which the second-growth stands consist almost entirely of sprouts and decay of the valuable butt log had seemed like an insuperable obstacle. The results of dissection studies of thousands of trees in this forest type were applied in the latter part of the stand-improvement operations of the CCC and have been developed to a point where they can become immediately useful again as soon as post-war conditions provide man power.

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For ponderosa pine of the Black Hills and the Southwest, in which heart rot has caused losses commonly 25 percent or more of the merchantable volume, modified management including both selection of safe crop trees and pruning to keep them safe was developed in cooperation with the Forest Service, and the CCC and put into effect on large areas. Studies are under way designed to do the same thing for Douglas-fir and to make practicable large-scale control of the very destructive leafless mistletoe of ponderosa pine. These two species together supply nearly half of the entire saw timber cut of the United States.

Regarding Douglas-fir and white oak research has discovered external signs of hidden decay or liability to decay which have been put into use on national forest land in cruising timber and in determining which trees can be safely left for a later cut in areas where sustained-yield production is being attempted. For the species studied it has been abundantly demonstrated that modifications in forest management can be made which will greatly decrease the losses and uncertainties due to heart rots and bark diseases without any special expenditure for disease control alone.

Foresters have been aided in fire control in three important regions by studies of the decay of logging slash, in which it has been shown that the fire hazard from the slash can be decreased as or more rapidly by the use of cheap and easy methods of slash disposal than by the more expensive piling methods originally considered necessary. Deterioration studies conducted in areas where trees were killed by bark beetles, fire, and windthrow, respectively, have supplied information as to the rate of deterioration of the killed timber and the salvage schedules required to avoid heavy losses.

Nursery Stock Diseases

Early large-scale introductions of the white-pine blister rust were largely the result of the losses and uncertainties caused by nursery stock diseases in this country. Because of difficulty in producing their own stock the nurserymen turned to importation with all of its dangers. The damping-off disease of pine seedlings, the most serious cause of uncertainties in production of native nursery stock, was attacked early in the course of the forest pathology work.

By distinguishing losses due to excessive heat from those that were produced by fungi, and developing chemical soil treatments for use where damping-off fungi were responsible, the production of seedlings was made both cheaper and more dependable and the need for extensive importation from abroad was removed. During the rapid expansion of nursery production by the Forest Service and the Soil Conservation Service, as part of the program of the Commodity Credit Corporation, it was possible to provide the tree-growing agencies with advice and technical service through which heavy initial losses both in the seedbeds and in stock in storage and transit were brought under control in later operations. Certain diseases due to stem and root parasites have yet to be brought under control but the most common and serious nursery diseases no longer endanger planting programs.

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Forest Products Laboratory of the Forest Service. In the species most used for aircraft wood and plywood the discolorations present at the time the trees are cut have been studied: Sitka spruce and Douglas-fir at the time of the first World War, and yellow birch, yellow poplar, and sweet gum since Pearl Harbor. This has resulted in the use of quanities of high-grade wood formerly rejected because of suspected infection. This is true of spruce and yellow poplar in particular. No sacrifice of safety is involved. In the case of yellow poplar it is estimated that the findings already made available to plywood producers and inspectors make possible a 20-percent increase in the yield of aircraft grades.

Blue stains caused by fungi in the sapwood, particularly of pine and sweet gum, which reduce large quantities of it to the lower and unprofitable grades, became subject to extensive study in 1929 in cooperation with lumbermen and chemical companies. Methods were developed that proved cheaper and easier to apply than those previously used, and more effective on pine and much more effective on hardwoods. These were rapidly adopted by the industry, representatives of which had estimated their annual losses due to these stains at $10,000,000 a year. More than 4,000,000,000 feet of lumber, or approximately one-sixth of the total cut on saw timber, was treated during the last year for which complete records are available; it is found that the treated material is not only improved in appearance and price but on the average is more shock resistant and less often infected with decay organisms in seasoning or storage.

Decay of Wood in Buildings and Fence Posts

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Decay of Wood in Buildings and Fence Posts

Decay in buildings and the factors that favor it have been studied

through many years. It has been found that proper drainage of sites, substructure ventilation, and wall construction which will allow the dissipation of water that enters through joints, together with care to place no untreated wood in contact with soil, will prevent the serious sporadic cases of decay which have influenced builders in many cases to go unnecessarily into the use of more expensive building materials.

The generally improved building practices to which educational effort connected with this study has contributed have gone far to prevent the increase in building decay which would otherwise have occurred with the high percentage of sapwood in the lumber now available. Special studies to aid the defense housing agencies were begun a year before the United States entered this war. As a result, Government housing agencies have been informed by special publications which precautions were necessary and which unnecessary in building the type of houses without basements produced by thousands for war workers.

In cooperation with the Soil Conservation Service, studies of locust for fence-post use have been nearly completed which show that some varieties are much more resistant than others, and that the decay resistance differs greatly with age and position in the tree. This work provides a basis for better selection of varieties for planting purposes and better utilization of timber not only for fence posts but for other uses in which decay resistance is required. The studies have been extended to the oaks with indications that similar results will be obtained, and the fundamental facts will facilitate a study of decay resistance of woods available for tropical construction now being undertaken as a service to the defense of tropical America.

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SECTION VII

SOILS AND FERTILIZERS

Bulletin No. 4 of the Weather Bureau, issued in 1891 just after that Bureau became part of the Department of Agriculture, discussed the physical properties of soils in their relationship to moisture and to crop production. The author of this bulletin was Milton Whitney of the Maryland Agricultural College and it was based upon his own original work. Soon after, Whitney began to work on soils in the Weather Bureau.

In 1894, Whitney was Chief of an independent Division of Soils which, in 1901, became the Bureau of Soils, and it was headed by him throughout its existence, except for the last 3 months when A. G. McCall was Chief. In 1927 the Bureau of Soils merged with parts of the then Bureau of Chemistry to become the Bureau of Chemistry and Soils. This new agency itself disappeared as such in 1938 when research work on soils was transferred to the Bureau of Plant Industry and the other soils' work to the Soil Conservation Service.

Originally the Division of Chemistry studied soils in relation to the growth of specific crops, like sugar beets, as well as the effects of drought conditions and the influence of cultivation on soils, as related to their physical properties and moisture content. In the very early days of the Department its chemists also became interested in the problem of soil exhaustion and the remedial measures required. The Division of Chemistry also undertook investigations of the spread of plant diseases by

soil bacteria. These soil studies continued in the Bureau of Chemistry, hence the merger in 1927 was a natural one.

In 1915 work on the identification of definite but complex organic substances in soils was placed in the newly organized Division of Soil Fertility in the Bureau of Plant Industry. In 1928 the Division of Soil Chemistry and Physics was formed by merger of two Divisions that had previously been independent in the Bureau of Chemistry and Soils. In 1938 this Division was transferred to the Bureau of Plant Industry where, in 1942, it merged with the Divisions of Soil Microbiology and Fertilizer Research to become the Division of Soil and Fertilizer Investigation. The name of the Bureau was changed to Bureau of Plant Industry, Soils, and Agricultural Engineering in February 1943.

Washing and gullying were mentioned in reports of Department scientists as early as 1901. A report issued in 1907 declared that American rivers took a billion tons of soil sediment to the sea every year, emphasized the dangers of run-off, and presented the facts about soil erosion very clearly. It was also stated that eroding soils could be saved by contour cultivation, proper drainage, stripcropping, and the reforestation of land unfitted for agriculture. The report stated that the public must be educated to take individual and collective action to prevent soil erosion.

The great educator in this field soon appeared in the person of H. H. Bennett who started to work in the Bureau of Soils in 1903 and, in 1905, carried out a survey of a badly eroded section of the Virginia Piedmont in Louisa County. Bennett became Inspector of Soil Surveys about

1909 and from then until 1933 he and his coworkers made numerous references to the extent of serious erosion occurring in various soil types. In the last decade of this period Bennett became the foremost advocate of a national program of soil conservation.

Chiefly as a result of this agitation the Buchanan Amendment to the Agricultural Appropriation Act for the fiscal year 1930 was adopted. It provided for research on the cause and control of soil erosion, $160,000 being appropriated for the purpose of which $40,000 was made available immediately. Ultimately ten experiment stations were established for investigation on lands typical of particular erosion problems in various parts of the country.

A Soil Erosion Service was established in the Department of the Interior in 1933. It became part of the Department of Agriculture when the Soil Conservation Act was passed April 27, 1935, and the Department's Soil Conservation Service came into existence. The soil erosion experiment stations of the Bureau of Chemistry and Soils were moved into this agency. Included were drainage investigations and experiments and demonstrations in connection with the construction and hydrologic phases of farm irrigation and land drainage, previously carried on in the Bureau of Agricultural Engineering.

Early Accomplishments

When they were started under Milton Whitney soil investigations had an appropriation of only $2,000. The immediate objectives were to ascertain soil moisture and temperature conditions and to make soil analyses. As

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early as 1895 it was suggested that soils could be classified on a basis of their analyses. During this time the work was closely related to geology, though publications were issued on soil moisture, texture, and soluble-salt content. Meanwhile the Division of Chemistry was reporting on soil constituents, and on the physical character, composition, water-holding capacity, humus, nitrogen, potash, and phosphorus content of soils.

By 1897 the Division of Soils had undertaken a notable investigation of tobacco soils and soil survey work was begun in 1899. Soil mapping now got under way, detailed soil surveys of localities in Maryland and in Louisiana were made, and much attention was devoted to alkali soils. By 1900 the tobacco investigations had progressed to the point where shade-grown Sumatra was widespread in Connecticut, and it was calculated that the results of this research alone would save producers and consumers of tobacco $15,000,000 annually.

A little later Oscar Lowe, who had been in charge of the notable tobacco fermentation studies, left for the Tokyo Royal Agricultural College in Japan at four times the salary he had received in the Division of Soils. It was then estimated that the results of his work in the Department of Agriculture saved tobacco dealers in Pennsylvania alone a million dollars a year.

In the report for 1903, Whitney reviewed certain conclusions he had reached as a result of research in the Division. He then held that there was no apparent correlation between crop yields and the dissolved salts in soils, because many soils which contained plant nutrients in abundance varied widely in agricultural value, some of them producing extremely poor

crops. Whitney held that all soils contained the necessary plant nutrients, but that the fertility level of a soil could not be determined by mere chemical analysis. Mechanical conditions, moisture content, soil management, and climate were all important factors.

By 1905, maps were being constructed that graphically represented the classification, occurrence, and distribution of different soil types. Around this time the use of fertilizer by farmers came in for study, it having been observed that much fertilizer was wasted by unintelligent application. There were now Divisions of Soil Utilization and of Soil Erosion in the Bureau of Soils. The former was established in 1901 and discontinued in 1908. Thereafter increasing emphasis was placed upon the use of drainage, dams, and proper tillage methods as soil-conservation measures.

Soil Surveys

The two chief figures in the development of soil science in the Department were Milton Whitney and C. F. Marbut. The latter was appointed a cooperative agent in the Bureau of Soils in 1909, leaving the University of Missouri at Whitney's urging. Marbut directed the soil survey work and made it one of the outstanding scientific enterprises of the Nation, to say nothing of the great impetus he gave to soil research in other countries.

Marbut early conceived of soil types as geographic entities to be studied both as individuals and in their relationship to the landscape as a whole. He visualized the urgent necessity for exact knowledge of these soil entities. When Marbut came to the Department soil data were isolated

and scattered. The general soil classifications had been based on the geology of the underlying rock formations, method of formation, topographic similarity, relief, and drainage, though soil texture, soil structure, and the organic-matter content of the soil were also considered. Marbut developed a system wherein scattered facts and data acquired meaning and significance.

Marbut published several books and many papers, his most important work being The Soils of the United States, which formed the final section of the Atlas of American Agriculture. Death overtook him on August 3, 1935, while he was in Harbin, Manchukuo, en route to China to examine certain Asian soils at the request of the Chinese Government.

During the latter part of the nineteenth century soil science had been dominated by the balance-sheet theory of plant nutrition formulated by Liebig. According to Liebig the soil was a sort of storage bin of plant nutrients. If you analyzed the soil and the plant you could calculate the number of crops that could be grown or the quantity of fertilizer required. The theory is simple and logical, but only approximately true.

Milton Whitney became interested in the physical characteristics of soils and these studies in soil physics opened up new lines of thought. He also saw the necessity for studying soils in the field and expressing the results on maps so as to give reliable information to farmers.

The first actual report of a soil survey was the initial volume of the Field Operations of the Division of Soils, report No. 64. Whitney outlined his views in the introduction, then followed soil survey reports for the Pecos Valley, N. Mex., Salt Lake Valley, Utah, the Connecticut

Valley, and some reconnaisance surveys. As the field work continued, lack of correspondence was found between the geological character of the underlying material and soil characteristics related to agricultural production. Drainage and soil color were also recognized as important.

By 1924 Marbut had outlined modern soil science, although his formulation was built upon pioneer research carried on during the previous 30 years which had mostly remained without synthesis or interpretation. By 1927, Marbut was the world's greatest single figure in the field of soil science and Liebig's balance-sheet theory was all but dead. By 1930 the principles of soil classification had been rather well worked out and it became necessary to interpret these classifications in quantitative terms as related to agriculture.

The soil surveys themselves are now made at a cost of from 5 to 10 cents an acre. A very conservative estimate of their value would be $1 an acre. The armed forces attributed a value of $300,000 to one survey because of the information it supplied in the construction of one airport.

The surveys are basic studies of the physical and chemical condition of soils, the types of crops or trees that will best grow upon them, the kind, quantity, and quality of fertilizing materials they require, along with informative large-scale maps in color. They also indicate the crop yields that may be obtained from each soil type under different management systems, and the effect of these systems upon the long-time productivity of the soil. They are absolutely fundamental to any rational program of land utilization in peace or in wartimes.

Other Soil Research

Around the turn of the century F. K. Cameron assumed charge of the Laboratory of Soil Chemistry of the Bureau of Soils. Under his direction notable work was done on the soil solution, soil fertility, and the physical chemistry of soils. It was established that soil phenomena are essentially dynamic in character, the influence of water, atmosphere, minerals, and biological factors keeping the soil solution in a state of continuous change. This concept greatly influenced later workers.

Oswald Schreiner and Edmund C. Shorey were associated with Cameron. Shorey's Farmers' Bulletin No. 921, on The Principle of Liming Soils, issued in 1918, was the first publication summarizing information on this important subject. It was widely used and proved extremely valuable. Cameron's book, The Soil Solution, was an influential publication.

The results of Cameron and Schreiner convinced Whitney that the soil water or soil solution was the principal factor determining soil fertility. He maintained that one of the chief functions of fertilizers was to counteract certain toxic substances which Cameron and Schreiner found in soils, and which they incorrectly assumed to account for infertility. Their mistake was in believing that substances toxic in water cultures were also toxic in soils.

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About 1919 work on the soil colloids was actively undertaken in the Division of Soil Chemistry. During the following decade definite progress was made in working out methods of preparing soil colloids, ascertaining the quantities present and their properties, and studying the relationship between their properties and their chemical composition.

More emphasis was placed around 1928 upon the relationships between the chemical composition of soils, their colloidal fractions, and soil classification. At least a dozen technical bulletins as well as many journal articles reported these studies. As a result, many recent chemical data from different parts of the world now tell much more about the character of the soil than previously.

About 1931 investigations were begun on the causes of a livestock ailment called "alkali disease" which occurred in several western States. The element selenium transmitted from soils to edible plants was shown to be the cause. These investigations, published in a series of technical bulletins and many journal articles, constitute one of the most carefully conducted researches of the Department. They have led to noteworthy economic improvement in grazing practices in extensive western areas. Horace G. Byers, in charge of this work, pioneered here.

Meanwhile Carl F. Kellerman and his associates discovered and described the soil bacteria which decompose cellulose. This was a definite forward step in our knowledge of the decomposition of agricultural plant residues. The discovery that these bacteria function in composts has greatly influenced the addition of fertilizers to increase the decomposition of cellulose therein, and has therefore had considerable economic effect.

Felix Löhnis and Nathan R. Smith also studied the life history of soil bacteria and summarized their findings. This work stimulated much investigation of bacterial variations. It was found that bacteria have various growth phases and differ in appearance and characteristics, from time to time, and within prescribed limits. This knowledge has been of great benefit in both agricultural and medical bacteriology.

Harry Humfeld and Nathan R. Smith found that green plants decompose rapidly when plowed under and that they liberate plant food. The effect of this rapid decomposition, however, affects neiter the soil micro-organisms nor the composition of the soil more than a quarter of an inch away from the decomposing material. Such localized action in part explains why decompositon and nitrification take place only in acid soil.

In studying the control of root-rot diseases Francis E. Clark and his associates found that, if the bacterial flora of the soil are stimulated to develop during the weakest period in the life history of the cotton-root rot fungus, the fungus is killed out. They also found that if the wheat plant is properly nourished with nitrates and phosphates throughout its life span, it resists take-all disease. Practical utilization of these discoveries will save millions of dollars. Charles Thom, long in charge of soil microbiological work, should be mentioned as a notable scientist.

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(Over)

of geology in Mississippi from 1855 to 1873, who noted widespread erosion in that State. He described in detail the complete destruction of soil in certain fields left uncultivated after the Civil War. N. S. Shaler and W. J. McGee also pointed out the widespread occurrence of serious erosion in various parts of the country in publications of the Geological Survey in 1890.

One of the first publications of the Department of Agriculture to deal with erosion was Farmers' Bulletin No. 20, issued in 1894 as a joint publication of the Divisions of Chemistry, Soils, Forestry, and Botany. The effects of erosion and suggested control methods were discussed, the material being based on field observations of several writers. This work was not immediately followed up.

As a result of field studies, soil-survey workers in the Bureau of Soils also presented a number of observations on soil erosion. These reports began with the work of Jay A. Bonsteel and associates in 1900. J. G. Mosier of the Illinois Agricultural Experiment Station discussed the seriousness of erosion and the necessity for adoption of preventive methods in 1908. T. C. Chamberlin, the well-known geologist, at the conference of governors in the White House in the same year pointed out the necessity of erosion control. In 1911, W. J. McGee discussed the mechanism of the erosion process and possible methods of control in Bulletin 71 of the Bureau of Soils.

Pioneer agitation by H. H. Bennett has been mentioned. Between 1914 and 1933 Bennett went on many missions to study soil conditions in the Canal Zone, in Alaska, in South and Central America, in Cuba, and elsewhere.

He published his book, Soils and Agriculture of the Southern States, and organized and directed the preparation of Bulletin 96 of the Bureau of Soils which classified the soils of the United States and described them in detail.

But dating from 1903 his primary interest has been soil erosion. In his report on Lauderdale County, Miss., issued in 1910, he gave an extended discussion of soil erosion and distinguished the eroded areas on a map by cross lining, one of the earliest attempts to map the erosion of soil. He also made therein the fundamental distinction between woodlands, pasture lands, and arable land which is still the basis for the major distinctions in land-use-capability classes.

In 1923, Duley and Miller of the Missouri Agricultural Experiment Station gave quantitative measurements of soil and water losses covering a 6-year period under a variety of types of plant cover and three fallow conditions in central Missouri. The investigators concluded, as a result of this work, that soil erosion was about the most important cause of soil depletion under Corn Belt conditions.

The net result of all this work was to indicate that no large geological division of the country was entirely free from problems raised by loss of soil and water. At the same time further information about the causes of erosion on important soil types and the best methods of control was not available. As was observed above, the Buchanan Amendment was passed as part of the Agricultural Appropriation Act of 1930:

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of increasing the absorption of rainfall in the soil in the United States, and to devise means to be employed in the preservation of soil, the prevention or control of destructive erosion and the conservation of rainfall by terracing or other means, independently or in cooperation with other branches of the Government, State agencies, counties, farm organizations, associations of business men, individuals...."

Plans were made to establish experimental work on lands typifying the large problem areas of eroding soil the country over. Ten erosion experiment stations were organized and their research programs got under way. These station programs are designed to investigate the causes and rates of erosion, and to ascertain the most effective practical methods of checking and controlling soil and water losses from agricultural lands.

The work includes the keeping of meteorological records, experiments with various types of vegetative cover, soil treatments, cultural and cropping systems and their comparative effectiveness in erosion prevention, studies of the performance of terraces and check dams of different designs in removing run-off without injury to soil and crops, and attempts to reclaim and revegetate eroded land. The investigations are carried out in cooperation with the State experiment stations.

The early work of the erosion stations showed the actual large amounts of soil that had been lost by various practices of continuous one-crop agriculture. The value of rotations in reducing soil loss was demonstrated as well as the notable protective effect of vigorous grass cover, which was found to be as efficient in this respect as a good stand of forest trees. The effectiveness and limitations of many cultural and mechanical methods

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The early work of the erosion stations showed the actual large amounts of soil that had been lost by various practices of continuous one-crop agriculture. The value of rotations in reducing soil loss was demonstrated as well as the notable protective effect of vigorous grass cover, which was found to be as efficient in this respect as a good stand of forest trees. The effectiveness and limitations of many cultural and mechanical methods

of erosion control, such as subsoiling, contour tillage, strip cropping, and terracing, were measured and thus a helpful fund of research information was accumulated.

The unique feature of the demonstration programs based on this information, and for which Bennett was largely responsible, was the consideration of the entire farm business of each cooperator as a demonstration project. This project was placed under an integrated farm plan which correlated the erosion control problem for related groups of farmers on a watershed basis.

To meet the varied problems of soil and water conservation presented first by the operations demonstration projects of the Service, and later by the Conservation Districts, the program of the original research stations was expanded. Several closely integrated research divisions were established.

The value of soil conservation research is enormous. Our annual soil erosion bill is more than $3,800,000,000. Of the 462,000,000 acres of good farm land in the United States, 342,000,000 are already in cultivation, the remainder being planted mainly to grass and trees. But only 62,000,000 of these good acres are not subject to erosion; another 70,000,000 acres could be protected from erosion by proper clearance, drainage, irrigation, and cultivating practices. Only then would the United States have an acre of cultivated nonerodible land per capita.

Wind and water erosion and bad land practices ruin about half a million acres a year. A billion acres, half of the Nation's land area,

really need some degree of protection. Furthermore, the use of methods of soil building and range building developed as a result of research not only saves the soil but also greatly increases crop yields and decreases the necessity for using so much fertilizer. The loss of a single inch of topsoil represents a reduction in nitrogen supply of at least 350 pounds per acre and of some 175-200 pounds of phosphoric acid as phosphorus pentoxide.

Little use was made of terrace-outlet channels to control incipient gullying from run-off water in the Southeast, before the Soil Conservation Service was organized. When the Service started its Operations Demonstration Projects, the best practice known was the use of an expensive series of check dams. In the fiscal year 1936 some 2,000,000 linear feet of outlets were put in to protect 130,000 acres at a cost of some $1,625,000, an expenditure of $12.50 per acre. These structures were expensive and subject to occasional failures.

Experimentation at the Spartanburg Hydrologic Laboratory developed a series of vegetative stabilized outlets in which grasses and other inexpensive plantings were used. At present, as a result of this research, terrace outlets are being installed at a cost of only $4.50 to $4.75 per acre. The large saving on 950,000 acres protected in 1940 amounts to more than the cost of the entire research program since it began in 1935.

Studies of sand-dune and wind-erosion control carried out in the so-called Dust Bowl, have resulted in wide application. The protection afforded agricultural land is estimated to run into millions of dollars.

It has notably reduced menaces to health and comfort of farm families who live in this region.

The work of the ten original erosion stations has now been expanded into the Division of Conservation Experiment Stations with 66 projects located in 38 States and 2 projects in Puerto Rico. Each of the work centers chosen exemplifies an area of special risk for soil and water conservation. The experimental results are extending and refining the information on methods of erosion control obtained at the original stations. The improved practices when applied to farm lands show savings in terms of natural resources that are difficult to evaluate in monetary terms.

The work of the other seven divisions of the Office of Research rounds out a well-integrated program. In the Hydrologic Division, studies concerned with the influence of land use and different types of vegetative cover upon run-off, erosion, and stream flow are being carried on in typical watersheds. The Sedimentation Division has determined the effect of the movement of erosion debris into reservoirs, stream channels, and valley fields. The mechanics of the movement of bed load and the fundamental laws governing the transportation and disposition of sediments are being studied by hydraulic laboratory research.

The Climatic and Physiographic Division has found the relation between soils and underlying land forms, in the occurrence of large-scale gullying, in critical erosion regions. Large-scale climatic studies have shown the way in which storms build up and the types that cause serious erosion. Work in erosion history has shown the course of early

attempts in erosion control and the reasons for successes and failures.

The Conservation Economics Division has determined the effects of soil conservation programs on farm income and farm living by study of the budgets and accounts of cooperating and noncooperating farmers and the damage from widespread erosion to municipal reservoirs has been demonstrated.

The Hillculture Division has shown the value of a number of new profitable erosion-control plants, such as shipmast locust, for planting on eroded, hilly farm land, and the possibility of augmenting farm incomes through such crops. The Farm Irrigation Division has made notable contributions to greater water economy in the western States, and in recent years has developed an effective system of forecasting stream flow from mountain areas, through snow surveys.

The Farm Drainage Division has ascertained the best depth and spacing of drainage tiles on a variety of soils and crops. In addition, new and improved types of drain tile have been developed for acid and alkaline soils. Drainage-district organization has been studied and possible improvements have been pointed out.

To make farm conservation plans, first on soil erosion demonstrations beginning in 1934 and later in assisting soil conservation districts, a need developed for large-scale maps showing the physical land conditions in each field or part of a field. H. H. Bennett and his associates worked out methods for making such maps, using the four factors—soil type, percent of slope, degree of erosion, and present use of the land. These surveys were called soil conservation surveys

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and to make them more easily understood, the various factors mapped were classified according to the use capability of the land. Specific recommendations for practices needed on each class of land were formulated and now are regular parts of the assistance extended to soil conservation districts.

The general soundness of the program of soil and water conservation research, as well as its close relationship to the welfare of farmers and farming communities, is shown by the fact that the research findings are proving of extraordinary value to the armed forces of our country in this war period.

Fertilizer Investigations

Fertilizer investigations had long occupied the Department's attention to some extent but our participation in the World War of 1917-18 made them doubly important. Research on nitrogen fixation actually began in the Bureau of Soils in 1915, a laboratory being set up at the Arlington Experiment Farm that year to test catalysts for the fixation of atmospheric nitrogen by the synthetic ammonia process. In 1917, the War Department became interested and supplied personnel both at Arlington and in the Bureau of Chemistry to carry it on.

On March 29, 1919, the War Department itself established the Fixed Nitrogen Laboratory, located at the American University, Washington, D.C. Its primary purpose was to utilize the Muscle Shoals fixed nitrogen plants for agricultural purposes. The Arlington laboratory personnel was transferred to the new unit. On July 1, 1921, the War Department

withdrew its support and the Fixed Nitrogen Laboratory became part of the Department of Agriculture, where it assumed an independent status until July 1, 1926, when it became part of the Bureau of Soils.

Specifically it was then absorbed into the Division of Fixed Nitrogen and Fertilizer Investigations which, in 1927, went into the newly created Bureau of Chemistry and Soils. On July 1, 1940, the Division was transferred to the Bureau of Plant Industry and, in February 1941, it was moved to the Beltsville Research Center, after having been continuously located at American University since 1919. The Division of Soil and Fertilizer Investigations was created July 1, 1942, and the work continues therein at the Beltsville Horticultural Station.

Fertilizer researches of the Department of Agriculture were inaugurated about 30 years ago when such research was practically nonexistent in this country, and when fertilizers were made up chiefly of low-grade waste materials. Nation-wide surveys for raw materials were first made, followed by technological work on their utilization and perfection of methods of synthesizing new products. Rapid progress added increasingly to the list of products available for use in the fertilizer industry.

As a result, the industry has been established on a truly chemical basis with an output of manufactured products having at present a total annual retail value to the farmer of about $250,000,000. Further benefits are manifested in present freedom from foreign sources of nitrogenous and potassic fertilizer materials, lowered costs of plant food, increased quality of the final products, and more efficient methods of utilization. The development of suitable fertilizers and methods

for their more effective use in raising food products, is of vital importance in peacetimes as well as in the present war.

<u>Nitrogen</u>

Investigations looking to the synthesis of nitrogenous fertilizer ingredients from atmospheric nitrogen were inaugurated in the Department in 1915 at a time when such processes were first being used in Europe but were still undeveloped in this country. By 1925 the major steps in the establishment of an American air nitrogen industry, based upon the direct synthetic ammonia process, had been taken. The Department developed an efficient and rugged catalyst for the synthesis of ammonia that was adopted in general commercial use.

Necessary data on the purification of gases and the chemical and physical behavior of the gas mixtures involved in the process were obtained. Apparatus and technique necessary to carry out at high pressures and temperatures the reactions involved were designed and perfected. The solubility of various gaseous constituents in liquid ammonia and in water at various temperatures and pressures were measured. Based upon these researches, and under the direction of workers drawn in large part from the Government's research staff, the present American synthetic ammonia industry developed rapidly. Cheaper nitrate nitrogen quickly resulted from the supply of cheaper ammonia.

In 1910, nitrogen in the nitrate form sold at wholesale in bulk for \$276 a ton, and in the ammoniacal form at \$264 a ton, but in 1942

the prices were $148 and $109, respectively. The savings to the farmers in the cost of nitrogenous fertilizers resulting from the establishment of the synthetic industry and the production of cheaper fertilizer products now amounts to at least $20,000,000 annually.

A method was developed for the synthesis of urea from ammonia and carbon dioxide, resulting in the establishment of a commercial plant furnishing this material to the fertilizer trade. Some work has dealt with the conservation of various types of waste products and their economical conversion into suitable fertilizers.

Phosphorus

Phosphate investigations have been concerned with the conservation and rational utilization of the Nation's phosphate resources and with the development of methods for the manufacture of cheaper and more efficient phosphatic fertilizers. Special attention has been given to the utilization of phosphate ores that are too low in grade for, or are otherwise not adapted to, the manufacture of the ordinary phosphatic fertilizers.

Investigations on the use of the electric furnace in processing both high-grade and low-grade phosphate ores resulted in the successful preparation, for the first time by furnace methods, of concentrated phosphoric acid suitable for direct use in the manufacture of concentrated fertilizers. This work formed the basis for the establishment of commercial-scale plants for the electric-furnace processing of

the prices were 2116 and 1109, respectively. The savings to the farmers in the cost of nitrogenous fertilizers resulting from the establishment of the synthetic industry and the production of cheaper fertilizer products now amounts to at least $100,000,000 annually.

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Phosphates

Phosphate investigations have been concerned with the conservation and rational utilization of the Nation's phosphate resources and with the development of methods for the manufacture of cheaper and more efficient phosphatic fertilizers. Special attention has been given to the utilization of phosphate rock that are too low in grade for, or are otherwise not adapted to, the manufacture of the ordinary phosphatic fertilizers.

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phosphate rock, including that of the Tennessee Valley Authority plant at Muscle Shoals. The first of these plants was placed in operation in 1920 under the direction of personnel trained in the Department.

Later the Department studied the application of fuel-fired furnaces to the manufacture of concentrated phosphoric acid. The results of this work led to erection of a large blast-furnace which produced phosphate chemicals and triple superphosphate fertilizer continuously for about 10 years. Attention was given to the production of both phosphorus and potash by the simultaneous smelting of phosphate and potash rocks, and a process was developed which offers promise of economic operation on a commercial scale.

A method was devised for simultaneously removing the fluorine from phosphate rock and producing a phosphatic fertilizer by heating the rock at high temperatures in the presence of water vapor. The product contains about 30 percent of available phosphoric oxide and is an excellent source of phosphorus for promoting plant growth. As this product contains little or no fluorine it has the additional advantage of being a very satisfactory phosphatic material for use in mineral supplements for livestock. Detailed laboratory studies of the process and product have been made in the Department and the large-scale development of the process has been investigated by several companies and by the Tennessee Valley Authority.

Potash

Before the organization of the German potash trust, farmers in the United States had been supplied with low-priced potash produced under highly competitive conditions. These conditions were terminated by a royal decree which placed the world's known potash supply in the hands of one monopoly and by the same act placed the farmers of the United States at the mercy of that monopoly. Not only would they receive that exploitation for which monopolies are organized, but also in case of war between Germany and a maritime nation all supplies of potash would be abruptly terminated.

This latter condition was realized during the World War I when the wholesale price of muriate of potash increased from $39.26 per ton in 1914 to $398.42 in 1916. Nation-wide surveys revealed resources of potash in both natural deposits and industrial wastes, and technological research showed how they could be utilized. The kelp groves of the Pacific were surveyed from the Mexican border to the Alaskan peninsula, and an experimental kelp-products plant was established on the West Coast where processes for the production of potash, iodine, and decolorizing carbons were developed and demonstrated.

Surveys of the salines and brines of the desert regions of the United States brought the discovery of the commercial value of the brines of Searles Lake, Calif., and a study was made of processes for the production of high-grade potash salts. Commercial development of these brines has resulted in the establishment of a manufacturing

plant with an installed capacity of 180,000 tons of potash annually.

The Department developed improved processes for the recovery of potash from cement kilns, blast furnaces, Steffen's waste, and distillery waste. These sources of potash were important during World War I.

That the farmer is the chief beneficiary of the establishment of an American potash industry is apparent. Not only is he assured of an adequate supply of potash in the future, but in 1942 they obtained their potash at a saving of $10,000,000 in comparison with 1910-1914 prices, and they also are in line to benefit from further reduction in manufacturing costs and transportation charges.

Mixed Fertilizers

About 25 years ago the Department initiated work that is bringing about the gradual elimination of filler and the use of high-analysis mixtures in many parts of the country. Double-strength mixtures have been developed, and are now in use in agriculture, that are similar in their chemical and physical properties and, for corresponding quantities of plant food, in their physiological effects to the best grades of single-strength mixtures.

Price schedules issued periodically by fertilizer companies show that the farmers, who use double-strength in place of single-strength mixtures, make a greater saving in their fertiliser bills than they would if the wholesale cost of all the plant food entering into the single-strength mixtures were cut in half. An average increase of

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about 20 percent has taken place in the plant-food content of fertilizers since this work was undertaken. The resulting saving in the freight, storage, handling, and bagging costs of fertilizers is now estimated to be $15,000,000 annually.

Adoption of high-analysis mixtures was in large part made possible through investigations of methods for improving their mechanical condition, reducing their tendency to burn crops, decreasing their acid-forming influence in the soil, and preparing mixtures that contain an adequate proportion of all the essential plant-food elements.

The method found best adapted for improving the mechanical condition of fertilizer mixtures, and particularly of high-analysis mixtures, involves a granulating treatment whereby the fertilizer is changed into spherical particles of uniform size and shape. This treatment greatly improves the drillability of the mixture, prevents segregation, reduces caking, eliminates the necessity for using high-priced organic conditioners, and decreases losses when the fertilizer is applied on a windy day.

As a whole, the Department's fertilizer investigations have been largely responsible for a present annual reduction of $45,000,000 in the fertilizer bills of the farmers of the United States, as compared with prices paid in 1910. These investigations have therefore made available an abundant supply of fertilizers for the growing of crops at lower production costs without impairing the fertility of the soil, and have furnished an essential aid for soil conservation.

SECTION VIII

ENTOMOLOGY

Work in the field of economic entomology started in the Bureau of Agriculture, which was inaugurated by the Commissioner of Patents in 1854, and was under the direction of Townend Glover who was appointed that year as "expert for collecting statistics and other information on seeds, fruits, and insects in the United States." Published with the annual report of the Commissioner of Patents for the year 1854, issued in 1855, is an article on insects injurious and beneficial to vegetation, by Glover.

When the Department of Agriculture was created in 1862 the work of the Bureau of Agriculture under the Commissioner of Patents was transferred thereto, and Glover was immediately made the first official entomologist of the Department of Agriculture. Thus he remained, with the exception of 2 years, until 1878, when the already illustrious C. V. Riley, the State Entomologist of Missouri, was appointed to succeed him. Riley was the first outstanding Government entomologist.

Riley's reports from Missouri were different from anything of the kind that had been published. They were sound and based mostly on study and observations, and were admirably illustrated. To him goes the credit for the founding of the United States Entomological Commission which prepared classical works on the Rocky Mountain locust and many other insects and insect groups.

Riley's investigations of the grapevine phylloxera saved the wine industry both in France and in this country. He conceived and directed the first notable successful introduction of parasites to control insects by bringing the Australian ladybird, or vedalia, to this country, which resulted in the saving of the citrus industry of California.

Later as other insects received attention, methods of control were proposed; on the other hand the promotion of beneficial insects like the honeybee was considered.

Later Departmental entomological work was long associated with the name of L. O. Howard, who entered the Division of Entomology in 1878 and became head thereof in 1894. He became Chief of the Bureau of Entomology when this was created July 1, 1904, and served until October 15, 1927. A Federal Horticultural Board was created June 29, 1912. In October 1927, it was replaced by a Plant Quarantine and Control Administration, and a Bureau of Plant Quarantine was created July 1, 1932. On July 1, 1934 work in entomology was combined with that concerned with plant quarantines when the Bureau of Entomology and Plant Quarantine was created.

Notable Workers of Early Days

As early as 1888, Dr. Howard had achieved an international reputation for his studies of certain parasitic hymenoptera. His mosquito investigations began in 1892, and, when these insects were found to transmit disease, he was ready to suggest control methods that did much to make effective the work of Walter Reed and W. C. Gorgas.

He did some of the early work on using insect parasites to control insect pests. His book on the housefly started a world crusade against its dangers. Had his recommendations on boll-weevil eradication been followed when the invaders were first found in Texas, the South would have been saved untold millions. His book, The Insect Menace, published in 1931, was widely read, and his History of Applied Entomology presents a fascinating account of the development of insect control work in this country.

Other Department entomologists were notable: D. W. Coquillett, who developed cyanide fumigation to control insect pests; H. G. Hubbard, who developed oil-emulsion sprays; W. E. Dove, the medical entomologist who discovered that endemic typhus may be transmitted by the tropical rat mite, which led to work of the Public Health Service which disclosed that fleas are also important vectors of this disease; and G. F. White, the investigator of many bee diseases, who also developed sterile-maggot therapy for osteomyelitis.

Early work of the scientists in this field was published mostly in annual reports of those in charge of entomological investigations. These entomologists did fundamental work in the development of fumigants and insecticides generally; they may be said to have founded the liquid-soap and oil-emulsion industries, which prevented much insect damage. Their introduction of natural insect enemies to eradicate domestic insects that were dangerous to various crops and fruits was ingenious and effective.

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Saving California's Citrus Orchards

In 1868 the fluted scale smuggled its way from Australia to the citrus-fruit orchards of California. It spread rapidly, attacking citrus and other plants. It so weakened many orchards that they had to be destroyed. The female secreted a dense, fluted, cottony mass as an egg which was practically impervious to the insecticides of the day. In 1886, C. V. Riley decided that an organism so obnoxious must have enemies somewhere and he determined to find them. As Australia was believed to be the native home of the pest he sent Albert Koebele to the island continent.

Koebele later sent back to California thousands of living parasitic and predacious enemies of the scale, among which was Vedalia (Rovius) cardinalis which proved to be the needed answer. This Vedalia beetle propagated and spread with amazing rapidity, stripping the scale from the trees. It saved the citrus-fruit industry of California. For the last 50 years it has kept the scale well under control.

Development of New Methods to Combat Insects

Between 1885 and 1895 Department entomologists developed many of the known successful basic methods of fighting insect menaces. Arsenic and other poison sprays were then first used. The first poison-gas attack took place during that period. Explorers went into many foreign countries to bring back natural predators of obnoxious insects. Many agricultural crops were spared virtual annihilation.

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Naturally much other work of basic importance in this field has been performed by Department entomologists and other scientists. For instance, work by some of them showed that plants resistant to certain bacterial diseases carried by insects could be bred by correct genetic crossing. Certain similar plants (that is, different varieties of the same species) are, and certain others are not, attacked by an insect. So attempts were made to breed plants that would resist the attacks of insects that do not carry germs but eat up the plant tissue.

This was accomplished in the case of the potato leafhopper's attacks on forage crops. It was found that the insect would feed on smooth but not on hairy leaves. Hence it seemed possible to breed hairy-leaved plants and avoid attack by the leafhopper. The scientific and economic potentialities of such research are enormous. (Pathological Symptoms in Legumes Caused by the Potato Leaf Hopper, E. A. Hollowell and John Monteith, Jr., Journal of Agricultural Research, 38 649-77 (1929.)

Entomologists have shown how to prevent a harmful insect from damaging crops by coping with it before it gets to this country. The citrus black fly, a pest of Asia, became established in Cuba before 1916 but had not entered the United States. The risk of its introduction into Florida and our other subtropical areas was great, so the insect was fought in Cuba.

Valuable experience was gained. The citrus black fly is not economically significant in Asia because parasites and predators keep it under control. One of its natural enemies was imported into Cuba and successfully extablished there. The percentage of parasitisation

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Other interesting research in the general field of entomology in recent years has concerned the possibility of breeding plants the fruit of which will be distasteful to insects but palatable to human beings, and an attack upon the Japanese beetle by artificially spreading the milky disease which affects its grub. Mention should be made of the work of G. F. White in the mass breeding of sterile maggots for therapeutic use, and William Robinson's rediscovery of the utility of allantoin found in maggots and urea found in allantoin in fostering the healing of stubborn wounds.

The problem of killing insects without using poisons injurious to human beings has taken an altogether new line during the recent years in which new types of insecticides have been discovered and utilized. The importance and long-time value of such investigations can scarcely be computed in monetary terms, but is certainly very great. Work accomplished in this field by Department entomologists and chemists is here described in more detail.

Grasshopper Control

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measure of noteworthy economic value. In 1884, D. W. Coquillet, a Department entomologist, observed crude attempts by California farmers to apply this method in grasshopper control and promptly brought it to general attention. The first practical large-scale use was initiated by entomologists of the Kansas Agricultural Experiment Station in 1913.

Since then great improvements in methods of application and in the reduction in cost of bait, accomplished by Department and State entomologists have made possible effective widespread cooperative campaigns to prevent the enormous losses of staple crops caused by outbreaks of grasshoppers. The value of crops saved by grasshopper-control operations in 1939, one of the worst outbreak years, was estimated to be more than $128,000,000, at a total cost to all cooperating agencies of approximately $5,600,000, or a saving of about $23 worth of crops for every dollar spent.

Breeding Insect-Resistant Varieties

Average annual losses due to the corn earworm are estimated at $98,000,000, to the chinch bug $15,000,000, and to the European corn borer $5,000,000, as instances. That some varieties of wheat and other cereal crops were less susceptible than others, or even resistant to the attack of certain insects, has been known for years. The 1797 edition of the Encyclopedia Brittanica speaks of a yellow-bearded variety of wheat said to have been imported into this country in 1781 and grown in the vicinity of New York City because resistant to the hessian fly.

The first systematic attempt to learn the comparative fly resistance of different varieties of wheat was made by C. W. Woodworth of the

California Agricultural Experiment Station and was reported in 1890. Similar observations by J. W. McColloch and S. C. Salmon, in Kansas about 1916, gave further impetus to the search. By 1942 this work began to culminate in the development of wheat varieties that are almost immune to the hessian fly, have high resistance to stem rust, leaf rust, and bunt, and give high yields of good quality.

Two fly-resistant varieties are now available for commercial production and it is believed that other and still better ones will come soon. The work of producing them has been carried on cooperatively for several years by State and Department of Agriculture entomologists, plant pathologists, and wheat breeders. General use of such wheats should go far toward eliminating the losses, estimated at $13,000,000 yearly, caused by the hessian fly.

Progress is being made in the development of corn varieties that are resistant to the earworm, the chinch bug, and the European corn borer, though the breeding techniques involved are more difficult than those used with wheat. Observations on earworm resistance in corn were made as early as 1917 (G. N. Collins and J. H. Kempton, Journal of Agricultural Research 11 549-72), and work has progressed rapidly of late. It has been shown that corn resistance to insects is heritable and a few insect-resistant lines are already being used in the production of commercial hybrids.

Independent observations by R. A. Blanchard and John E. Dudley, Jr. (Journal of Economic Entomology 27 (1) 262-4 (1934)) showed the existence of individual alfalfa plants on which the destructive pea aphid was unable to survive and breed. More recent Federal-State work has shown that the

California Agricultural Experiment Station and was reported in 1920. Similar observations by J. W. McColloch and S. C. Salmon, in Kansas about 1916, gave further impetus to the search. By 1942 this work began to culminate in the development of wheat varieties that are almost immune to the Hessian fly, have high resistance to stem rust, leaf rust, and bunt, and give high yields of good quality.

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Ladak variety and individual plants of Kansas Common and other varieties are highly resistant, the resistance being transmissible by breeding. No varieties possessing practical immunity to the aphid are yet available but apparently they soon may be.

If only 25 percent of the insect losses of the plants mentioned could be prevented by this research the saving realized in 1 year would pay for the years of investigation many times over. The practical use of insect-resistant varieties would involve little, if any, increased cost to the grower, and would free him from restrictions and expense imposed by the more-or-less unsatisfactory cultural and other control methods he uses. Varieties or lines of sorghums, oats, and barley that are resistant to one or more insects are being developed.

Control of the Corn Earworm on Sweet Corn

Until 1937 there was no known way of protecting sweet corn from the ravages of the corn earworm. During the summer of 1936, however, George W. Barber, one of the Department's investigators who had been working on this problem for several years, discovered that if about one-fourth teaspoonful of refined odorless and tasteless mineral oil was injected into the silk mass at the tip of the ear, after pollination was complete, fair protection from the earworm could be obtained without preventing the normal development of the kernels. It was also shown that the treatment can be safely applied as soon as the silks have begun to wilt and turn brown.

Protection from the earworm was created by the fact that the oil made its way among the silks and there formed a barrier through which the worms could not pass. Further investigation revealed that except in ears having moderately long tight husks this protection from earworm was not entirely satisfactory.

It next became necessary to provide an apparatus for use on commercial acreages that would deliver a reasonably accurate dose of the oil, because an excess of it proved harmful to the ear. This objective was attained by means of a simple modification of a low-priced oiler of the piston type attached by a short hose to a portable oil container. On small plantings, such as in home gardens, it was shown that the oil can be injected satisfactorily by means of an ordinary oil can or an eye-dropper with its tube marked so that the proper dose can be measured.

Further studies showed that the addition of a very small quantity of pyrethrum extract to the oil brought almost complete prevention of injury by the worms that entered the treated ears, without leaving any objectionable odor or taste in the kernels. Circular No. 657, Mineral Oil Treatment of Sweet Corn for Earworm Control, fully describing and illustrating this method, was issued in August 1942.

The oil-pyrethrum method of control has been favorably received by commercial growers of early market corn and in several sections of the country its use has proved highly profitable. In 1942 commercial sweet corn growers in the Coachella Valley of California realized a premium of 75 cents per box of 50 ears for corn thus protected, and a net profit of $140 per acre from this treatment. During the summer of 1942, it was

demonstrated that this method can be utilized profitably for the protection of valuable hybrid seed sweet corn in the Idaho seed-producing area.

Insects Affecting Sugar Plants

The beet leafhopper, commonly referred to as the "white fly" in the West, not only infests many crops, but also carries and transmits the virus of the destructive disease known as curly top in sugar beets and as western yellow blight of tomatoes. A single leafhopper may transmit the disease to several plants and a few disease-carrying leafhoppers may cause severe damage to plants in the seedling stage. For years, curly top disease has been a limiting factor in sugar beet production and many sugar factories have been abandoned because of its presence.

The development and successful production of beet strains resistant to curly top has reduced the magnitude of losses caused by the disease and has helped to stabilize the western sugar-beet industry. Knowledge of the beet leafhopper's life history afforded by entomological study has been of great assistance here. The entomologists have also shown that damage by curly top to sugar beets grown for seed may be reduced materially by using an oil spray containing pyrethrum. This was the work of V.E.Romney.

A discovery important to domestic cane sugar production was the demonstration by Department research workers, E. V. Abbott and J. W. Ingram, in 1941 that chlorotic streak, a serious sugarcane ailment, new to this country, is transmitted by a leafhopper commonly found feeding on Louisiana cane. It is hoped that this discovery may lead to improved

control methods for the means by which the disease was transmitted had been unknown. Discovery by Department investigators, E. W. Brandes, J. W. Ingram, and M. R. Summers, during the period 1917-36, that the destructive mosaic disease of sugarcane can be transmitted by both the rusty plum aphid and the greenbug, as well as the corn-leaf aphid, will be helpful in control work.

A New Principle of Insect Control

The leafhopper Empoasca fabae (Harr.) was recognized by Herbert Osborn as a potato pest in 1896 and "hopperburn" injury was briefly described. Later workers found this insect also destructive of alfalfa, clover, apple, bean, and other crops, but the nature of the injury remained mysterious. Work by F. F. Smith and F. W. Poos, in 1931, showed that over accumulation of carbohydrate products above the point of injury by the insect resulted in the development of characteristic symptoms in the plant. Detailed life-history studies of the insect followed. Control of the pest on such crops as alfalfa was effected by delaying the time of cutting the first crops until most eggs had been laid by spring migrants, while the application of bordeaux mixture of pyrethrum-sulfur dust gave control of peanut, bean, and potato plants.

In the course of this work D. M. DeLong showed, in 1929, that bean leaves sprayed with bordeaux mixture absorbed enough copper to be toxic to leafhoppers feeding on the cell contents. This set up a new principle of insect control which has not yet been fully exploited. Various Department workers have also shown that pubescent or hairy varieties of clover,

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apple, and soybeans are less severely injured by this leafhopper than are glabrous or smooth ones.

Conquering the Heelfly

Ill effects of heelflies or cattle grubs have been known since the time of Virgil, and possibly before. Early European workers published many, and often contradictory, articles on the subject which first received attention in this country in the 1880's by C. V. Riley. In 1890, Cooper Curtice reported finding larvae of the insects in the bodies of animals. He assumed that the cattle became infested by licking the eggs or young larvae from the hairs on their bodies.

Riley accepted this theory of transmission by mouth; but it was disproved between 1917 and 1926 by systematic investigations of F. C. Bishopp and others in the Bureau of Entomology. They showed that the newly hatched larvae could directly penetrate the skin near where the eggs had been attached to the hair, while no grubs developed in animals fed heelfly eggs and newly hatched larvae. These findings were confirmed by other workers.

Later rotenone-bearing powders, derris and cube, were proved to be particularly efficacious for killing the encysted grubs on the backs of cattle. The use of sprays containing rotenone powder, or of benzol and iodoform ointment, which entails more exacting technique, has been shown to afford effective control.

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Controlling the Peachtree Borer

The peachtree borer, a native American pest, is very destructive to peach orchards. A single borer can girdle a tree and soon cause its death. Until control measures were devised the borer was a limiting factor in peach production, and the only known method of control until 1919, was to dig the borers out by hand--a laborious and time-consuming process. But in 1919, E. B. Blakeslee, a Department entomologist, announced his discovery that the borers could be effectively controlled at the cost of a few cents a tree by use of paradichlorobenzene.

The chemical occasionally injured the younger trees, and in certain northern localities the time for its application conflicted with harvest time. Investigation of the insect was resumed, and in 1936, Oliver I. Snapp, and J. R. Thomson reported on a new control method--the use of an ethylene dichloride emulsion. The method was rather generally adopted and seems certain to occupy an important place in peachtree borer control henceforth, although the matter of tree injury is under further study. A benefit of 10 cents a tree, the cost of treatment included, for these treatments is extremely conservative and if, as estimated, 16,000,000 trees a year receive one of the treatments developed by Department workers that alone amounts to annual saving of $1,600,000.

Development of Smear EQ 62 for Use Against the Screwworm

"Smear EQ 62," a combination screwworm larvicide and wound protector, composed of 35 parts each of diphenylamine and benzol, 10 parts of turkey

red oil, and 20 parts of lamp black, is the result of 5 years of intensive research and combines three fundamental discoveries.

The observation that phenothiazine when applied to wounds would not prevent screwworm flies from ovipositing, nor eggs from hatching, but was toxic to newly hatched larvae, suggested the practicability of a finely divided nonrepellent material as a wound protector against infestation. Approximately 1,000 selected compounds were tested in the laboratory and the more promising of these were subjected to field studies. On the basis of performance, cost, availability, staining properties, and toxicity to higher animals, diphenylamine was recommended for general use.

Benzol, the recommended larvicide at the time, possessed the disadvantage of nonmiscibility with blood, serum, and wound exudates which reduced its effectiveness in deep and profusely bleeding wounds. The addition of turkey red oil to benzol was found to overcome this objection and materially enhanced its effectiveness as a larvicide.

At this stage two separate treatments, that of a larvicide and that of a wound protector, were required. Results of studies on combining the two treatments showed some promise. It was apparent, however, that two major factors contributed to the mediocre performance of these combinations.

In the first place, upon evaporation of the benzol a large portion of the diphenylamine crystals were too large to be devoured by the young larvae and thus were ineffective. Then these combinations were so fluid that only a thin layer—and thus a small qualtity of diphenylamine—could be applied to the wound surface.

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In the study of fillers which followed, it was found that certain grades of lamp black added body to the mixture thus permitting a heavier application of diphenylamine to the wound, and had the remarkable property of producing extremely fine diphenylamine particles upon evaporation of the benzol. Thus Smear EQ 62 was finally perfected.

Vacuum Fumigation

Vacuum fumigation—that is, reducing the air pressure in a chamber containing a commodity by removing most of the air in and around the commodity and then applying the fumigant in this partial vacuum—originated in the Department of Agriculture. The first work was by E. R. Sasscer and L. A. Hawkins in 1915, who tested this method in the fumigation of seed and showed that, with hydrocyanic acid applied according to this method, insects in seed were killed without injury to the seed, with a considerably shorter exposure than was necessary in the usual method of seed fumigation at atmospheric pressures.

The first large-scale application of this process was in fumigation of baled cotton which was authorized as a quarantine measure in 1916 for application to imported cotton from areas infested in pink bollworm. The process was later adapted to the fumigation of domestic cotton in pink-bollworm-infested areas in this country, and during 1929 and 1930 considerably more than 500,000 bales were fumigated each year.

The process has been adapted to fumigation of rice, wheat, corn, and cereal products, nut meats, dried fruits, tobacco, potatoes, and many other commodities. It is widely used, not only in the United States,

but in foreign countries, and is one of the standard methods of insect control. Products valued at many millions are freed from insect infestation by this method each year.

Development of Japanese Beetle Traps as a Survey Device

The Japanese beetle, of oriental origin, was first found in 1916 in New Jersey just east of Philadelphia and has now occupied an extensive area along the Atlantic seaboard. Efforts are being made to retard its spread to other parts of the country. As a means of ascertaining how far the Japanese beetle has gone, in connection with efforts to prevent its spread, Department scientists have developed effective traps which reveal the presence of the beetles even though they may occur in such small numbers that diligent search without the traps might fail to find them.

In the course of research the scientists found, about 1924, that the Japanese beetle was strongly attracted to geraniol and eugenol, two common materials used in the perfume industry. Further work developed an effective trap to which many beetles can be attracted by the odor of the bait, and thus captured.

Although the value of the traps in direct control is doubtful, they have been found extremely useful as scouting devices in the program for preventing spread. In addition, when used in large numbers in isolated light infestations, the traps appear to have considerable value in keeping these infestations from increasing and serving as new centers of spread.

Control of the Japanese Beetle by the Milky Diseases and Parasites

Among the numerous natural controls utilized in the fight against the Japanese beetle, the milky diseases, caused by certain species of bacteria, have given outstanding results. Japanese beetle grubs affected by these diseases become milky white in appearance, with the blood assuming a milky color and consistency. Fortunately, the milky disease organisms are entirely harmless to plant life, domestic animals, and human beings, although fatal to the Japanese beetle.

These diseases proved to be of such value in beetle control that the Department undertook, in cooperation with different State agencies in the region concerned, a program of colonizing these organisms at suitable points throughout the beetle-infested areas. This program has been under way since the fall of 1939, and, through 1942, in the neighborhood of 42,000 colonies representing some 27,000 acres have been treated with the milky disease organisms in 12 States and the District of Columbia. From these colonies the disease is spreading through the immediately surrounding areas, and at the points where the earliest colonies were placed has already reduced the infestation materially.

Special attention has been given to the District of Columbia and adjoining areas, where more than 6,000 acres of infested turf in park areas have been intensively treated. This work has already brought striking reduction in the numbers of beetles and grubs, and has reduced the damage to shade trees.

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Special attention has been given to the District of Columbia and adjoining areas, where more than 6,000 acres of infested land in park areas have been intensively treated. This work has already brought striking reduction in the numbers of beetles and grubs, and has lessened the damage in these areas.

A method has been developed for the mass production of the spores of the milky disease organism, the living Japanese beetle grub being used as the medium for growing the spores. The rate of multiplication of the spores of the milky disease in the bodies of infested Japanese beetle grub is tremendous, the number which may be found at the time of death of the grubs varying from 3 to over 7 billion spores per grub. These spores are mixed with talc and lime, and since the fall of 1939 some 65,000 pounds of the spore-dust material have been produced and distributed in the field.

The Department first began intensive work toward biological control of the beetle in 1920, with the assignment of trained entomologists to study the beetle in its native home, Japan, where the pest is kept down by natural control agencies. Some 26 species of insect parasites and predators of the beetle and closely related species were sent to this country for study, and of these, 16 were liberated in areas infested by the beetle. Five species of parasites of the beetle are now well established in a number of areas, where they are certain ultimately to be of value in keeping the Japanese beetle population within bounds.

Vapor-Heat Treatment of Citrus Fruit

Vapor-heat treatment was developed on a commercial scale by the Department of Agriculture in Florida during 1928 and 1929 as a means by which fruit from areas infested with the Mediterranean fruitfly could be treated and then shipped to market without danger of disseminating the pest. The initial laboratory studies on which the method was based had

been made previously, but the results were not put to practical use until the appearance of the fruitfly in Florida. The treatment essentially consists in heating the fruit to a temperature of 110° F. and holding it at that level for 8 hours.

The equipment required consists of an insulated room, usually having a capacity of one carload of fruit, in which the fruit is stacked in shallow boxes. The air is withdrawn from the floor of the room and conditioned in a special unit on the outside where steam and water sprays keep it at the desired temperature level and at complete saturation. A large blower provides forced circulation, and it must have a sufficient capacity to circulate the total volume of air several times per minute. After this conditioning, the air is reintroduced into the top of the room and spreads evenly over the load so that all of it is heated uniformly.

A heating period of several hours is necessary to bring the mass temperature of a carload of fruit up to 110° F. Many hundreds of carloads of citrus fruit were so treated in Florida in 1928 and 1929; the practice was discontinued there when eradication of the fruitfly was accomplished.

This method was authorized in 1938 for the treatment of citrus fruits from areas in Texas restricted because of the Mexican fruitfly. In 1939 and 1940 a total of 44,150 and 8,926 tons, respectively, of grapefruit were thus treated before they were forwarded to northern markets. In the same year it was authorized for the treatment of Hawaiian fruit and vegetable hosts of the Mediterranean fruitfly and the melon fly, to allow shipment to the continental United States.

Use of Heat in Control of Insects on or in Plants, Fruits and Vegetables

The use of heat is probably one of the oldest methods of insect control, for it has been available to man for many centuries. At first it was used inert materials where a relatively wide margin existed between the points where lethal effects to insects were evident and where the material upon which the insects occurred was endangered. During the past decade the development of methods of automatically regulating the production of heat has made it possible to maintain constant temperatures with ease, and these have been used in numerous instances to produce dependable and effective control methods.

Until about 1937 no noninjurious insecticide or fumigant had been found that would effectively control insects such as borers, mites, bulb flies and bark beetles, that feed within plant parts or larvae that feed internally in fruits and vegetables. About the only available means of reaching individuals of this group was to heat the host material, whether plants, plant products or fruit, to a point where the insect was killed but the host was not injured. This usually required the use of a accurate procedures, as the margin between the temperature required to kill the insects and that at which plant injury takes place is very small.

For growing plant material two methods were developed which have proved to be successful: (1) Submersion in warm water, a method originated by European workers, and (2) exposure to warm, saturated air. Both were usually done at 110° F.

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Until about 1927 no satisfactory insecticide or fumigant had been found that would effectively control insects such as weevils, mites, bulb flies and bark weevils, that feed within plant parts or larvae that feed internally in fruits and vegetables. Hence the only available means of reaching individuals of this group was to heat the host material, whether plants, plant products or fruit, to a point where the insect was killed but the host was not injured. This usually required the use of accurate procedures, as the margin between the temperature required to kill the insects and that at which plant injury takes place is very small.

For treating plant material two methods were developed which have proved to be satisfactory: (1) submersion in water using a method originated by European workers, and (2) exposure to warm, saturated air. Both were usually done at 110° F.

The second method originated in the Department and was mainly developed by it. Vapor heat was first applied to the treatment of citrus fruits for removing the hazard of disseminating the Mediterranean

fruitfly. It was later approved for treating citrus fruits for the Mexican fruitfly and papayas for the Mediterranean fruitfly, and for extensive treatments of strawberry crowns infested with Tarsonemid mites.

Both methods were adapted for the treatment of various plant hosts of the cyclamen and related mites and of flower bulbs for mites, mealybugs, bulb fly larvae, lily thrips, and gladiolus thrips. Many of the uses of hot water and vapor heat have been supplanted since 1937 by methyl bromide fumigation.

The method of immersing narcissus bulbs in hot water to rid them of bulb fly larvae, bulb mites, and the bulb scale mite was developed and perfected by J. K. Ramsbottom of England in 1918 and by E. Van Slogteren of Holland in 1919. This method was used for the first time in the United States during 1926 and has been reported upon by a number of Department workers at various times between then and 1940. It can also be used for tuberose and other bulbs; commercial growers have found it extremely valuable.

L. O. Kunkel, of the Boyce Thompson Institute, in 1926 discovered that aster yellows, a destructive disease of China asters, was caused by a virus transmitted by the six-spotted or aster leaf-hopper. More than 200 species of plants other than the aster, in more than 30 families, are susceptible to the disease, and effective control methods have been developed, particularly for lettuce, endive, and asters.

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Eradicating Poultry Lice

The discovery of sodium fluoride as an insecticide for the control of poultry lice and the development of simple, practical methods of employing this material, resulting from work by F. C. Bishopp and H. P. Wood in 1927, are outstanding accomplishments from the standpoint of farmers and poultry raisers generally. Some 20 editions of the bulletin describing this work have been issued to a total of 1,220,000 copies. This is still the standard treatment used. It is effective, yet it is so simple that a boy can apply it.

The Bark Beetle

Since the earliest days of forest-insect investigations there had been real need for sprays that could be applied to the bark of trees or logs to prevent attack by bark beetles and wood borers, and to kill such insects as were boring beneath the bark. About 1919, B. A. St. George of the Bureau of Entomology found that orthodichlorobenzene had some such insecticidal properties and by 1929 it was in widespread use for the purpose.

Barkbeetle control was always laborious and difficult in forestry also, involving much manual labor in felling and bucking trees and then either barking or burning them. Hence foresters continually requested the entomologists for a spray that would kill barkbeetle broods and render control easier.

About 1931 the orthodichlorobenzene-fuel-oil spray was tested against the western pine beetle in California, and it has since become a cheap, standard practice for the control of mountain-pine beetles in lodgepole and to a lesser extent in white pine where these trees grow. Further improvement in these sprays has rendered them increasingly effective against vectors of the Dutch elm disease.

Insecticide Investigations

The value of research on the chemistry of the compounds used in controlling insects was early recognized by the Department and was put on an organized basis by the passage of the Insecticide Act in 1910. For years the work was directed mainly toward the enforcement of that Act, but on July 1, 1927, impetus was given by the establishment in the Department's Bureau of Chemistry and Soils of a division devoted wholly to research work on insecticidal materials.

On September 1, 1934, this Division of Insecticide Investigations was transferred to the Bureau of Entomology and Plant Quarantine in order to coordinate it more intimately with the entomological work of the Department to which it is so closely related. Since 1927, under the leadership of R. C. Roark, constant efforts to improve already known insecticidal materials and to develop new ones have been made, and the Division has published nearly 650 papers covering all phases of insecticidal work.

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An illustration of the many important lines of work that have been followed is found in the work on fish poisons. Starting with the practice

that any plant used by savages to stun or kill fish might logically be expected to yield some constituent that is toxic to at least some insects, plants from all over the world were collected and studied. It soon became evident that among these the ones containing a certain chemical called rotenone took front rank.

Considerable chemical work had been done previously on derris from the East Indies, and certain rather restricted insecticidal uses had been found for its powdered roots, but the intensive chemical study of it made in the Insecticide Division resulted in the first elucidation of its chemical structure. This achievement was recognized in 1933 by the award of the Hillebrand Prize of the Washington Chemical Society to F. B. LaForge and H. L. Haller, who, with the assistance of L. E. Smith, solved this difficult problem.

Publicity resulting from this chemical research so spurred collateral insect testing that rotenone rapidly took its place as the principal insecticide for control of pea aphid, Mexican bean beetles, and other insects. In 1929, rotenone was discovered by E. P. Clark in a wild plant known as cube, used for fish poisoning in Peru. The demand for this type of insecticide, built up in the United States mainly through the Department's work, stimulated rapid expansion in the importation and use of this plant which now is furnishing all of our rotenone, since the supply of derris from the East Indies has been cut off by the war.

In 1933, rotenone was shown by an Insecticide Division worker to be the active constituent of a native plant known as the devil's shoestring,

the insecticidal activity of which was previously demonstrated by a State worker in Texas. Other Department workers took up the problem of breeding the originally poor-quality stock up to an acceptable level of quality.

The value of the work on rotenone is illustrated by the fact that in 1941 more than 9,000,000 pounds of rotenone-bearing roots were imported, a quantity sufficient to make 90,000,000 pounds of insecticidal dust of 0.5 percent rotenone content. Ten years earlier rotenone roots were not commercially obtainable.

The United States Patent Office has granted 89 patents to members of the Division of Insecticide Investigations. These patents describe valuable inventions, such as new processes for making cryolite, one of the most important mineral insecticides; two processes for the purification of pyrethrum concentrates; an apparatus for determining the particle size of powders, in wide use not only by insecticide manufacturers but also by manufacturers of cement, paint, and other commodities; the use of ethylene oxide and a mixture of ethylene oxide with carbon dioxide as an insecticide which is in world-wide use as a fumigant; a process for making nicotine bentonite, one of the most satisfactory substitutes for arsenate of lead for control of codling moth larvae; and xanthone, 2-chlorofluorene, phthalonitrile, and many other synthetics that have great toxicity to insects.

Cotton Insect Investigations

From the beginning of cotton production in colonial days, the bollworm and the cotton leafworm caused great damage and the control of these insects was among the first important problems brought to the attention of entomologists in this country. The Report Upon Cotton Insects prepared by J. H. Comstock, entomologist of the Department of Agriculture in 1879, was epoch-making and at that time was the most comprehensive document on economic entomology published in this country. This was followed by the publication in 1880 of the large illustrated Bulletin No. 3 of the United States Entomological Commission on the cotton worm by C. V. Riley and, in 1885, the Fourth Report of the United States Entomological Commission devoted more than 600 pages to the cotton worm and bollworm.

The spread of the boll weevil from Mexico into Texas in 1892 and its establishment in that State during the next 10 years was the direct cause of great expansion in entomological research and in the growth and activities of the entire Department of Agriculture. The present Extension Service that has done so much to bring the latest results of research to farmers during the past 40 years, was an outgrowth of the farmers' cooperative demonstration work started by the Department to meet the boll weevil problem.

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the early investigations and recommendations of Townsend, Howard, and Mally, from 1895 to 1900. These studies were continued by dozens of others and comprise the most extensive investigations that have ever been made of one insect. The discoveries made in connection with boll-weevil investigations have had a wide influence in the insect-control programs throughout the world. New industries have evolved as a result of this work.

Calcium arsenate was developed as an insecticide for the control of the boll weevil during World War I. The manufacture and use of this material have gradually expanded, until during 1941, and again in 1942, more than 70,000,000 pounds of calcium arsenate were used for the control of cotton insects in this country.

As early as 1919 airplanes were used under the direction of W. D. Hunter of the Bureau of Entomology for locating both fields of cotton in areas that had become infested with the pink bollworm and mosquito-breeding areas that were otherwise concealed from view by wooded lands. An airplane was first used for the application of an insecticide on August 3, 1921, when 6 acres of catalpa trees at Troy, Ohio, were dusted with lead arsenate for the control of the catalpa sphinx. This successful experiment conducted by entomologists of the Ohio Agricultural Experiment Station was followed by rapid developments in the use of airplanes for the application of insecticides to control cotton insects.

At the laboratory of the then Bureau of Entomology at Tallulah, La., investigations were conducted in cooperation with the Bureau of Public Roads and the United States Army Air Service over a 10-year period from

1922 to 1931. A staff of entomologists, engineers, chemists, airplane pilots, mechanics, and others was engaged on this project and much progress was made in designing hoppers and testing airplanes and methods of application. The second successful test of the use of airplanes in the control of an important insect came during July and August of 1922 when airplanes were used for applying calcium arsenate to several fields in the Delta section of Louisiana and Mississippi for the control of the cotton leafworm.

From these experiments it appeared that the application of insecticides from airplanes gave better results than from ground machines. During that summer preliminary experiments showed that calcium arsenate applied by airplanes gave effective control of the boll weevil. Almost immediately airplane dusting of cotton was adopted as a commercial practice. By 1926 a number of commercial companies were engaged in airplane dusting of cotton, chiefly in Texas and Louisiana. It is estimated that in recent years, each season, at least 200 airplanes have been operated by two dozen organizations engaged in crop dusting for the control of insect pests and plant diseases.

Methyl Bromide as a Fumigant

The first use of methyl bromide as a fumigant for insect control in the United States was by D. B. Mackie of the California State Department of Agriculture in 1937. The first tests were on white potatoes for the potato tuber moth. Soon afterward, the Bureau of Entomology and Plant Quarantine tested and approved methyl bromide fumigation for the treatment of fruits and vegetables to free them of adult Japanese beetles, and thereafter studies of the method extended rapidly.

Methyl bromide is relatively noninjurious to plants when used at strengths sufficient to be effective against a wide variety of insects. It is now used in the fumigation of mills, warehouses, and seed houses for the control of insects that attack grains and cereal products, and in special gas-tight- chambers or vaults for the fumigation of these products as well as potted or balled-and-burlapped plants.

A method of soil fumigation using methyl bromide diluted with water has also been developed. Thus larvae of both the Japanese and the white-fringed beetles in soil areas and in balled nursery stock can be destroyed. Other nonexplosive fumigants now in general use that were studied or developed by Bureau personnel are chloropicrin for soil and grain, ethylene dichloride-carbon tetrachloride for general purposes, ethylene dichloride-carbon tetrachloride-methyl bromide mixture for grain, and ethylene oxide-carbon dioxide for grain and general purposes. Additions are being made to this list all the time.

Artificial Insemination of Honeybees

Artificial insemination of queen honeybees gives scientists a new instrument for exploring a field which has been virtually closed to them for many centuries. Other than to place hives of bees in isolated places many miles away from known domiciles of honeybees, it had not been possible to control the mating of queen and drone with any degree of certainty. Consequently, although there are several distinct races of honeybees, several of which readily intermate, honeybees had remained much the same during the many years when notable improvements had taken place in other branches of agriculture.

In 1923, C. W. Quinn and H. H. Laidlaw created a great deal of interest in bee breeding by their efforts to effect matings between queens and drones by hand manupulation. A very definite advance was made in 1926 when L. R. Watson, of Cornell University, demonstrated the successful instrumental insemination of queens.

This achievement took place at a time when the country was gradually coming to the realization that, in addition to being the sole source of honey and beeswax, honeybees occupied a much more important role in pollinating some 50 agricultural plants. Many of these plants produce better and bigger crops when honeybees are abundant and several of them must have bees or other pollinating insects to produce any crop at all. In this category are many pasture and forage plants, fruits, and garden seed crops.

While continuing to work and improve this method of controlling matings in honeybees, the Department is making an extensive study of existing races and strains of honeybees. It is studying their genetic make-up and cataloging their characteristics, such as resistance to disease, propensity for stinging, honey gathering, and pollinating ability, hardiness, and longevity. It is doing this against the day when, with scientific accuracy and background, it will combine these various characteristics into strains developed genetically for special purposes.

The Department is working with strains that differ in quantity of honey produced - as much as 100 pounds per colony per year. In cooperation with several agricultural experiment stations, it is conducting research and carrying on extensive tests of strains which will resist

foulbrood, a contagious disease of young bees which results in the loss of thousands of colonies annually. The work on resistance to disease shows great promise and lends encouragement to the practicability of improving honeybees in various other respects.

Development of the Plant Quarantine System

The United States was the last of the economically important countries to impose restrictions on the entry of plants and plant products, and it was only after several years of consideration that Congress passed the Plant Quarantine Act of August 20, 1912. Before that date such injurious pests as the San Jose scale, codling moth, hessian fly, cotton-boll weevil, oriental fruit moth, potato wart, chestnut blight, and numerous others with great destructive capacity were introduced and had become firmly established. The history of these pests tells a depressing tale of crop destruction, economic losses, increased production costs, expensive control measures, and troublesome readjustments. It has been estimated that the losses in the United States occasioned by introduced insects, not to mention plant diseases, approximates $1,500,000,000 annually.

Following the passage of the act a foreign-plant quarantine system was developed with the aim of preventing the further entry of insect and plant-disease aliens with the minimum of cost or disturbance to normal commerce or the essential needs of horticultural development. This has involved the establishment of prohibitory and restrictive quarantines, the development of a permit system, the placing of plant quarantine inspectors at ports of entry, perfecting methods of treatment, etc.

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Experience has demonstrated that the job is not completed by merely inspecting the products which enter under permit. It is necessary to be constantly on the alert for other avenues of pest entry. Hence, inspection also includes the examination of vessels, railway cars, airplanes, automobiles, parcel post packages, passengers' baggage, and in the case of freight cars returning from Mexico, the fumigation of many of them in Federal car-fumigation houses on account of the pink bollworm of cotton. During the fiscal years 1935 to 1939, inclusive, 234,858 interceptions of insects were made at American ports of entry, many of which are not known to occur in the United States.

The plant quarantine system thus established is closely integrated with the field of science in many respects. For proper functioning and normal progress those operating it must rely on and be constantly kept apprised of the best available scientific information. A wide knowledge of plants is indispensable, not only those constituting agricultural crop species, but also those which act as hosts for pests and as sources for imported commercial products. Hence the plant quarantine system must have at its command an intimate fund of world-wide information in the several branches of botany.

Entomology is basic. In the systematic field the quarantine entomologist is virtually called on to determine the identity of any of the world's vast range of insects. As an economic entomologist he is expected to know their hosts, their habits, and their life histories from the quarantine point of view, and to devise methods for their elimination from imported materials or for limiting domestic spread.

Equally important is plant pathology. There is required, on the one hand, the identification of the world's vast number of pathogenic fungi, bacteria, viruses, and nematodes, together with an understanding of their life histories, habits, and the symptoms by which their presence can be recognized and, on the other hand, a knowledge of treatments and procedures the use of which will allow safe entry from abroad or safe movement domestically.

In part, the need for special information is met by research activities within the Bureau of Entomology and Plant Quarantine itself, particularly in relation to insect pests. Here studies are made on the classification and identification of insects, occurrence and habitat records are maintained; life habits are investigated; host and climatic relations determined; control measures worked out; and methods of treatment to destroy individual insect types are sought out and tested. On the other hand, this Bureau relies largely on the Bureau of Plant Industry for special research in plant pathology.

The Insect Menace

This country is so large and offers so many climatic and nutritive opportunities that the raising of fruits, vegetables, cereals, and fiber crops must constitute an unrelenting and unending war against insects. Modern means of rapid transport by air also enable insects to get into the country more readily than ever before. The slightest relaxation of entomological control measures, accepted by us thoughtlessly as natural, would result in enormous losses or utter destruction of entire crops.

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Insect and disease problems change constantly. About 1870 the San Jose scale was introduced into California from Asia. In 1880 the gypsy moth from Europe was first found in the United States; in 1892 the boll weevil came in from Mexico; in 1917 the European corn borer was found to have emigrated here from Hungary; in 1916 the Japanese beetle appeared from Japan, and so on. When the Graf Zeppelin made its second trip to this country in 1929 plant quarantine inspectors found on the plant material it carried 20 species of insects, 6 of which were not known to occur in this country. Fast airplane transportation makes vigilance increasingly urgent.

Necessity for continuous research on methods of coping with destructive insects is indicated by the fact that insects, mites, and ticks occasion losses in this country estimated at more than $3,000,000,000 annually. It is estimated that in North America there are nearly 80,000 different kinds of insects. In the records of the Insect Pest Survey are notes on more than 20,000 species of these, at least 10,000 of which are pests of some importance. Much of the loss occasioned is preventable and has been prevented in considerable measure as a result of research carried on by Department entomologists and chemists.

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SECTION IX

NUTRITION AND HOME ECONOMICS

For generations it has been theoretically recognized that the final purpose of agriculture and industry is to turn out goods that the public will buy and use and that an efficient national economy depends on efficient consumption as well as on efficient production and distribution. But the problems of the individual consumer are so complicated and the ordinary home represents so small a capital investment and has so little to do with money profit, that research has been inclined to pass them by.

The Department of Agriculture was the first great scientific organization in this or any other country to attempt to correct this lack by setting up a Bureau of Home Economics, with the double function of conducting research into the principles behind the efficient utilization of agricultural products in the home and of spreading reliable information on these subjects. This Bureau is the only Government research agency that deals primarily with problems of the ultimate consumer.

An outstanding exception to the neglect of consumer problems was in the matter of food and human nutrition. For a century or more many citizens had recognized the connection between national welfare and diet, as witness an article on the Proportion of Nutriment of the Means of Living in the annual report of the Patent Office for 1847, and a Report

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on the Food and Diet Suitable for Almshouses, Prisons and Hospitals, published in 1852 by the Board of Immigration. These papers would hardly pass as scientifically valid today, and really reliable work had to await the development of improved methods of food analysis and physiological chemistry. It was not until 1869 that W. O. Atwater, mentioned earlier, made the first published proximate analysis of an American food material--that of American corn.

With the establishment of State agricultural experiment stations from 1875 on, the way was opened for more extensive scientific work with human foods. In 1888, the Office of Experiment Stations was organized, and in his first annual report the director, Atwater, said:

"It has been urged by not a few of the best thinkers and wisest agriculturists and economists that in studying the food of animals we have no right to neglect the food of man. The principles involved are essentially the same. The majority of our people and practically all wage-workers spend and must spend at least half the money they earn for food. *** The need and the wisdom of such studies require no urging."

From 1894 to about 1914 Congress provided special funds for nutrition investigations in the Department of Agriculture. Other phases of home economics came into the picture as public interest developed. Home economics courses multiplied in schools and colleges, agricultural and home economics extension work appeared. In 1914, the nutrition investigations were enlarged into an Office of Home Economics under the direction of C. F. Langworthy.

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In 1923 the States Relations Service was abolished and the Bureau of Home Economics was created, with Louise Stanley as chief. This step was taken as part of a general reorganization of the Department by the then Secretary of Agriculture Henry C. Wallace, and in response to agitation by various women's organizations. The Bureau's home economics research, under Dr. Stanley, now included food and nutrition, textiles and clothing, household equipment, and such economic considerations as the use of money and household labor.

On February 23, 1943, the Division of Protein and Nutrition Research was transferred from the Bureau of Agricultural Chemistry and Engineering to the Bureau of Home Economics which then became the Bureau of Human Nutrition and Home Economics. Dr. Henry C. Sherman was appointed chief and Dr. Stanley became a special assistant to the Administrator of Agricultural Research.

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Early Research on Food and Nutrition

It was fortunate for home economics research that its principal beginning was in the nutrition investigations of the Department of Agriculture, one of the best planned programs of scientific research ever carried out in this or other country, and one which placed its director, Wilbur O. Atwater (1844-1907), high in the list of Department scientists.

Soon after Atwater had finished the usual classical course at Wesleyan University, Middletown, Conn., he happened to fall in with leaders of the new movement for scientific agriculture and saw in it such professional opportunity and chance for social service that he went to the Sheffield Scientific School at Yale to study agricultural chemistry. He soon realized that to be abreast of developments one must go to Germany. So he studied for 2 years at Leipzig and Berlin and saw at first-hand the work of the pioneer German experiment stations.

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His interests gradually centered more and more on human nutrition and he returned to Europe to study physiological chemistry in Munich and Heidelberg and to visit the leading European laboratories. Back in the United States once more he began the first systematic studies of American foods and diet. In collaboration with the Bureau of Fisheries, he analyzed samples of several hundred fish and other sea foods--the first extensive study of the composition of American food materials--and with Carroll Wright and the Massachusetts Labor Commission he carried out pioneer American studies of actual diets.

Many laymen as well as agricultural and social scientists were beginning to see the vital relation between the Nation's food and its economic and social progress, and urged that the Federal Government do something to encourage research in human nutrition. Two such opinions are recorded in the annual reports of the Secretary of Agriculture.

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Public pressure increased until in 1893 Congress appropriated $10,000 for investigations of the problems of human nutrition, to be made under the Secretary of Agriculture and in cooperation with the State agricultural experiment stations and colleges, and suitable public and private agencies. Atwater was made special agent in charge, with headquarters in Middletown, where he could both direct the new work and continue his own investigations.

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When Atwater's health broke down in 1904, the United States was a recognized leader in nutrition research. Without his courageous persistence and his skillful and far-seeing leadership, this eminence would not have been won so quickly. American nutrition research has an enviable reputation for scientific accuracy, and in this, too, it owes much to the high standards he set for the nutrition investigations.

Food Composition

Basic to all study of nutrition is the composition of food materials. Even before the nutrition investigations were organized, Atwater had begun compiling the results of available American analyses, finding most of the data in the work of the Bureau of Chemistry and in his own analyses. In 1896 appeared the first edition of Office of Experiment Stations *Bulletin* 28, The Chemical Composition of American Food Materials. It soon became the food student's bible both here and in many other countries.

In 1918, this publication was officially adopted by the Inter-allied Food Commission. Most of the food-composition figures in American books and articles on food and diet have been taken from it. Countless institutions, physicians, dietitians, and students have used it to calculate the nutritive value of diets, not to mention the Army and Navy. Up to 1940 the Government Printing Office had distributed 116,704 copies.

The Bureau of Home Economics, now the Bureau of Human Nutrition and Home Economics, has continued to assemble data on food composition and

in 1940 a long-awaited revision of Bulletin 28 appeared. After vitamins entered the food picture, the compilations of proximate analyses were complemented with others of vitamin content. Because the Bureau has the largest available collection of basic data on food composition, the National Research Council has recently provided it with personnel to expedite the compilation of such data, especially in connection with new and less familiar foods that may be needed in feeding the armed forces.

Dietary Standards

To judge the nutritional adequacy of a diet, one must have some sort of standard for the amounts of the various nutrients that it should provide. These are ordinarily based on the daily needs of a man at moderately active muscular work, and so-called dietary ratios or factors are used to translate them into the requirements of other persons according to sex, age, and activity.

The first such standards commonly adopted were drawn up by Voit, the German physiologist, who based his figures on studies of diets actually consumed by families of German workingmen. In adapting them to American use, Atwater raised them to conform to our more generous diets and to avoid the danger of underfeeding in institutions and low-income groups. The Atwater standards were generally accepted here. As more knowledge of nutritional needs became available, they were frequently modified by both Atwater and his successors.

So too were the dietary ratios for calculating food requirements for different groups of adults and for children of different ages.

When minerals and vitamins assumed greater importance in nutrition, standards for these were added to the original ones for protein, fats, carbohydrates, and energy. In 1941 the nutrition committee of the National Research Council announced its technical standards and its much-popularized "yardstick of good nutrition." These now form the accepted standards for the United States.

The most notable development in the practical usefulness of dietary standards is the work of Hazel K. Stiebeling, food economist in the Bureau of Home Economics. To state it briefly, Dr. Stiebeling has translated the theoretical dietary standards into terms of actual food materials for individual family and national use, and by so doing she brought us a long step nearer to well-balanced nutritionally adequate diets for families at all income levels, and to the practical possibility of fitting food production to nutritional needs.

To do this she divided our common food materials into 12 groups according to their special nutritive value. Then she calculated what quantities and proportions of each would be needed in diets at four levels of cost: Restricted diets for emergency use, adequate diets at minimum cost, adequate diets at moderate cost, and liberal diets. The cheapest diet (slightly below the 1941 recommendations) was made up of quantities and proportions of foods from each group that together provide the necessary nutrients at least cost. The more expensive diets included more of the foods that improve flavor and variety as well as nutritive value.

Dr. Stiebeling also worked out the quantities of food from each group needed per year by adults and by children of different ages, and the approximate per capata quantities required annually to provide the population of the United States with each of the four diets. These suggested diets were immediately put to use when the country was faced with the problem of adequate diets for families hit by the depression. Stiebeling's figures for national requirements are constantly referred to in planning our national and local food production programs.

In 1942, the material was "stepped down" into handy weekly market lists for practical homemakers, each list being accompanied by simple directions and blanks for working out the quantities needed by a family made up of this or that number of adults and children. The suggested diets ranged in cost from $15 to $29 for a family of 2 adults and 2 children and, like the whole of the Stiebeling plan, allowed for plenty of individual choices within each group of foods. In the first 10 months after the lists were issued, over 300,000 copies were distributed, more than third of them by sale.

Dr. Stiebeling has been an influential official representative of the United States at several meetings of nutrition committees sponsored by the League of Nations, in both Europe and the Americas. Even in countries not accustomed to accept leadership from women, she is looked up to and consulted as an outstanding contributor to food economics. The tremendous food problems of the war and postwar periods are bringing out the fundamental valûe of her work.

<u>Dietary Studies</u>

For a true picture of dietary conditions, we must learn what normal people actually eat, and as food habits vary with region, racial traditions, income level, and other factors, we must learn this for all sorts and kinds of typical groups. The cooperative feature of the early nutrition investigations adapted them particularly well to a program of this sort.

Between 1894 and 1906, 485 of these studies were made. From them the Nation gained a clearer idea of the diversity of its dietary customs and needs, and dietary workers could plan diets for special groups with less danger of unnecessarily upsetting food habits.

The dollars-and-cents value of such work was shown in a large public institution in an eastern State, where a dietary study led to a per capita saving of 13.7 percent in the cost of the food served, while nutritive value and attractiveness were improved. Dietary studies have now become more or less a matter of routine in many institutions, and several States employ nutritionists to decrease food costs and at the same time improve diets in establishments where people are fed at public expense.

The most comprehensive picture of its food habits that any nation has ever gained has been drawn from the food data collected as part of the Nation-wide consumer purchases studies made in 1934-35 and 1936-37. These food figures, analyzed by the Bureau of Home Economics, show that: About one-fourth of American families have good diets, somewhat less than a half have fair diets, and over one-third have poor diets. In general, farm families are better fed than others. Although low

incomes give little money for food, large expenditures do not guarantee good diets. By and large, the quality of the average diet depends on the wisdom with which food is selected rather than on the income; and good diets follow many different patterns.

Digestion Experiments

When it comes to accurate calculations of the good the body derives from the food consumed, account must be taken of the fact that even the healthy, normal body does not use all the nutrients provided. The nutrition investigations attempted to supply much-needed knowledge on this point by means of digestion experiments. In these the proportion of nutrients digested from a given food or diet was ascertained by comparing the food intake and bodily excreta of a normal person during the experimental period. These proportions were called coefficients of digestion. Up to 1906, 685 experiments had been completed. In general, the nutrients and energy of animal foods showed higher coefficients of digestibility than vegetable foods. The coefficients of digestion for the ordinary mixed diet were given as: Protein, 92 percent; fat, 95; carbohydrate, 97; energy, 91 percent.

Respiration Calorimeter Experiments

The chemical changes that take place in the body are spoken of as metabolism. To understand what they are is an essential step toward establishing the basic principles of nutrition. Up to a certain point the metabolism of digestion was learned from carefully controlled

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digestion experiments. But those told nothing of the gaseous exchange through the breath nor did they give any direct measurements of energy exchange. It was generally assumed that the law of the conservation of energy held true within the living animal as elsewhere in the universe, but this had never been scientifically demonstrated.

To do this required the accurate measurement and analysis of the air breathed in and out and the measurement of the heat and moisture given off by the body. Physiological chemists in Germany had been experimenting with apparatus to accomplish this complicated task, but it was at Middletown that the first successful instrument for use with human subjects was built and operated.

This was known as the Atwater-Rosa (later the Atwater-Rosa-Benedict) respiration calorimeter, set up in the natural science building at Wesleyan University. To the ordinary visitor it looked like a big, copper-lined wooden box, but between the inner and outer walls were several others, separated by air spaces for the better control of temperature changes. The inner chamber was about 7 by 6 by 4 feet in size and was furnished with folding bed, cot, and table, and whatever apparatus a particular experiment might require.

There was a specially constructed window big enough for a man to climb through and a smaller aperture through which food and other articles could be passed in and out without loss of heat or air. Air was pumped in and out through ventilation tubes which were connected with measuring devices to show its temperature and water content when it entered and left the chamber, and with a system of aspirators for

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frequent sampling and analysis. To measure temperature changes in the walls of the calorimeter, thermocouples set at frequent intervals were connected with recording devices outside.

The amazing thing about the whole contraption was that it worked. Not only did the subjects keep well and reasonably comfortable through their incarceration (commonly 4 days and 5 nights, though some experiments were much longer) but the balance of matter and energy as determined by the apparatus checked almost perfectly with that calculated from the chemical analysis and energy values of the materials involved.

The construction of such an instrument called for work by a highly competent physicist, and Atwater was fortunate in enlisting the help of his Wesleyan colleague, E. B. Rosa, later Assistant Director of the National Bureau of Standards, who developed many of the physical features which made for the success of the calorimeter. Later improvements were made, with the help of funds from the Carnegie Institution of Washington and under the immediate direction of F. G. Benedict, a physiological chemist on Atwater's staff. Benedict's work as director of the Nutrition Laboratory established by the Carnegie Institution in Boston won international reputation and carried on the tradition of scientifically accurate research in the intricate fundamental problems of nutrition.

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at different rates of speed and for different lengths of time. On the possibility of finding out whether mental effort produced energy expenditures above that of the same subject under conditions of similar muscular activity, college students took examinations in the calorimeter and other subjects made abstruse mathematical calculations, but the rather negative results did not throw much light on problems of mental fatigue.

In some experiments the purpose was to learn how diets of high- and low-energy value affected the metabolism of different subjects; a picturesque feature here was the use of a professional faster as the subject. Sometimes the subject was given diets supplying different quantities of protein or fats from different food materials. Other experiments were made to throw light on the metabolism of certain mineral constituents of food. One of Atwater's many assistants in the calorimeter laboratory was young Henry Clapp Sherman, now an internationally known leader in nutrition.

Conspicuous among experiments made in cooperation with outside agencies were those planned for and reported by the Committee of Fifty for the Investigation of the Liquor Problem, to show how the energy of alcohol is utilized in the body. As physiologists expected, this energy was used as completely as that from other sources, though more quickly. Of course this had nothing to do with the other effects of alcohol, but the work did prove that alcohol was a food to the extent that it provided body energy. When this news leaked out, it led to newspaper and other notoriety very distressing to Atwater both as a scientist

and as a sincere believer in temperance temperately promoted.

In 1906, 2 years after Atwater's retirement, the headquarters of the nutrition investigations were moved to Washington, D. C., and C. F. Langworthy was placed in charge. The calorimeter was set up in the basement of the East Wing of the Department of Agriculture, There it was used not only with human subjects but in cooperation with the Bureaus of Animal and Plant Industry to study changes in the storage of meat, the incubation of eggs, and the ripening of bananas and other fruits. When the Bureau of Home Economics was organized the calorimeter was turned over to the Bureau of Animal Industry.

A similar but larger apparatus, constructed by Director Armsby at the Pennsylvania Agricultural Experiment Station, was successfully used in connection with problems of animal nutrition. Several others were built at the Nutrition Laboratory of the Carnegie Institution, some for human and some for animal subjects; they were used to study such fundamental problems as metabolism in persons of different age, sex, and physical condition, in cold-blooded animals, and in connection with many types of muscular activity. All these calorimeters were expensive to build and operate, and after aiding in establishing general underlying principles of metabolism, they have gradually given way to less complicated methods of investigating individual features of the total problem.

Vitamin Studies

By the time the Bureau of Home Economics was established, vitamins had been added to the list of essential nutrients, but there was a dearth of information about their occurrence in different foods and the effect of cooking, freezing, and storage on their potency. Consequently the Bureau set up a laboratory for investigating such subjects by assays with rats and guinea pigs.

There it has made vitamin tests with hundreds of foods, both fresh and after treatment by commercial and household methods. A large proportion of these have been made at the request of other bureaus and of the food industries. Others have been part of the regular home economics investigations into the effects of home methods of cooking, canning, drying, and storage on vitamin content.

Before this war, a study was undertaken with normal human subjects to determine their vitamin A requirements. In this their visual adaptation to a change from dark to light was used as a measure of vitamin A sufficiency in the diet. A few experiments with human subjects were also made to determine their utilization of the vitamin A values from different food sources. The work with human subjects has been discontinued for the duration.

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Somehow, vitamins caught the interest of the public from the first, and as our knowledge is still far from complete, there has naturally been a great deal of loose talk about them. In the hope of lessening popular confusion, a very simple folder, Vitamins from Farm to You, was issued in August 1942, in which were pointed out the limitations of our information on, as well as our understanding of, their nutritive values. During the first 4 months after publication, 650,000 copies were distributed.

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During the Food Conservation Campaign in 1917-18, the demand for practical, reliable information about cooking, canning, drying, and storing food became so great that an experimental kitchen was established in the Office of Home Economics, with Minna C. Denton in charge. The general plan was to combine methods of scientific measurement with ordinary household procedures and to organize the "service" testing so that it would yield immediately useful information and at the same time accumulate a systematic body of knowledge about the effects of preparation, preservation, and storage on the nutritive value, healthfulness, palatability, and economy of food used in the home.

Despite the pressure for special services, Dr. Denton succeeded in keeping up regular work on a few subjects, such as canning, breadmaking, jellymaking, and the use of fats in cookery. She also succeeded in maintaining high standards of scientific accuracy in all the work of the kitchen. As a consequence, the Farmers' Bulletins and other popular articles issued on this work established the reputation of the Department as a source of information at once scientifically valid and practically useful to the homemaker.

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methods. The Bureau's own work on the bacterial content, palatability, and appearance of foods put up by different methods and stored for different lengths of time and under conditions like those in the ordinary home, together with the compilation and evaluation of work elsewhere, enabled it to prepare simple publications in which the practical directions were based on reliable research.

The first Farmers' Bulletin on home canning was widely adopted as standard. The seven revisions have together reached a circulation of about 13,000,000 copies. Dr. Stanley, while Chief of the Bureau of Home Economics, constantly insisted on safe, thoroughly tested methods and this largely accounts for the present high standards of home canning in the United States. Now that the tin, rubber, and other materials needed for containers of home-canned foods are scarce, the study of food dehydration in the home is a major project.

As a piece of long-continued, carefully planned research, the study on meat cookery perhaps leads. Carried forward as a cooperative study between the Department, the experiment stations, and industry, the purpose was to discover how the table quality of meat is affected by breed, age, and feed of animal and other factors. Between 1925 and 1943, the cooperators supplied about 2,200 cuts of beef, 3,800 cuts of lamb, 1,900 cuts of pork, and nearly 1,000 turkeys and chickens for use in cooking and palatability tests under the immediate direction of Lucy M. Alexander.

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had measured the internal heat of the meats by means of specially constructed thermometers, and similar thermometers were made for the later work. The cooperative meat project also adapted the Illinois methods for discovering other changes because no better ones had been developed in the years between.

Accurate records were kept of the cut, general character, weight of each piece, of the temperature and length of cooking, and of the losses in weight. The palatability is tested by a carefully selected group of tasters who judge and consider each cooked product for aroma, texture, flavor of fat, flavor of lean, tenderness, and quality and quantity of juice.

Aside from the commercial value of the investigations to producers and distributors, great improvement in meat cookery in the home has resulted. For example, the investigations proved that "holding in the juices" of meat is a matter of temperature control—cooking at moderate heat—rather than searing the outside, as had been long supposed. Recipes in standard cookbooks, women's magazines, newspapers, and advertising have been so changed since the Bureau gave out the practical results of its studies that one writer calls it a "revolution in cookery."

The home economics staff is constantly called on to study the possible home use of a great variety of new products. The study of baking qualities of the soft-wheat flours that came on the market from new wheat-producing areas after World War I is one example. Now much time is being given to the uses of soybeans as human food because this protein-rich vegetable food is likely to prove an important

wartime substitute for the meat, eggs, and other protein foods on which our armed forces and allies naturally have first claim.

Whatever the food material, this experimental cookery calls for a more thorough understanding of the chemistry of cookery and of scientific method than many people realize. Despite our romantic notions about how much better American cooking was in grandmother's day, the fact is that present standards of food preparation in the average American home are much higher than they used to be.

Food Facts for Everyday Use

Now an internationally acknowledged leader in the interpretation of scientific knowledge on foods and nutrition into terms of daily diet, the Department of Agriculture owes much of its prestige in this field to the distinguished and original work of Caroline L. Hunt. Unconventional, friendly, always on the search for new ideas, she was a striking and familiar figure about the Department from 1909 until her death in 1927.

While living at Hull House, she was asked to conduct dietary studies of low-income groups in that part of Chicago for the Department's nutrition investigations. In the course of that work she became so convinced of the social value of applying scientific knowledge to everyday life that she threw herself whole-heartedly into the home economics movement. Her unusual talent for clear, simple, accurate and readable writing on science applied to home problems led to nearly 20 years employment in the Department of Agriculture.

wartime substitute for the meat, eggs, and other protein foods to which our armed forces and allies naturally have first claim.

Whatever the food material, this Departmental cookery calls for a more thorough understanding of the chemistry of cookery and of scientific method than many people realize. Despite our romantic notions about how much better American cooking was in grandmother's day, the fact is that present standards of food preparation in the average American home are much higher than they used to be.

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It was Caroline Hunt who first popularized the idea of discussing the well-balanced diet in terms of five food groups. In preparing such _Farmers' Bulletins_ as A Week's Food for an Average Family, issued in 1921, she made innumerable calculations of dietary values, she planned, prepared, and tested inexpensive, palatable meals that illustrated the principles she was trying to explain, and she consulted with nutrition experts, extension workers, and homemakers from all parts of the country. The pictorial charts and bulletin illustrations she planned set new standards for accuracy, clarity, and artistic quality in the popularization of dietary science.

Nowadays the publications include not only bulletins and charts, but posters, leaflets, radio scripts—almost all the modern devices for popularizing scientific information. The total distribution of the Department's printed materials on food and nutrition is now more than 30,000,000 copies, the great majority of them simple, practical, how-to-do-it material for the homemakers.

Textiles and Clothing

Unlike food and nutrition, textile and clothing research in the Bureau of Home Economics had to begin practically at scratch. The starting point for the program was the national need for efficient utilization of cotton, wool, and other agricultural products for clothing and home furnishings. In 1924 Ruth O'Brien was appointed to organize the textile and clothing work and is still in charge. As she saw it, such a research program should involve studies of the

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relative merits of different kinds and grades of fiber when made into fabrics; determinations of the effects of use and methods of care on fabric deterioration; the development of suitable designs for different materials and garments; and the systematic study of methods of construction and repair.

The textile work, begun in one or two small rooms in an office building, is now carried on at the Beltsville Research Center in laboratories as completely equipped for textile research as any except a few in large industrial organizations.

Because cotton is our cheapest and most abundant fiber, some of the earliest research was on the determination of the characteristics of widely used cotton fabrics, and the effects on them of laundering and wear. The work on such fabrics as turkish toweling, sheeting, and cotton broadcloth ultimately led to the Bureau's drawing up specifications for their construction which have been adopted by the American Society for Testing Materials and other recognized standardizing agencies.

Similar work on blankets, corduroy, upholstering materials, and other fabrics has helped ordinary consumers in judging the quality of the goods they buy. Just now suitings are being tested in which reprocessed wool and rayon are combined with new wool. Studies of the construction used in ready-made garments are the basis of consumer buying guides for boys' suits, and women's coats, and dresses. The OPA frequently uses Bureau findings in its attempt to prevent "hidden degradation" of goods for which it fixes prices.

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Studies of causes for cotton deterioration led to the development of a new process for making fabrics mildew-resistant, which was released under a public-service patent granted to Helen Robinson of the Bureau's staff. Another public-service patent has been granted to Harry Humfeld, James H. Kettering, and Ruth Elmquist Rogers, for a method of sterilizing wool and other animal fibers without damage to the fiber. Both patents resulted from cooperation between microbiologists of the Bureau of Plant Industry and textile specialists of the Bureau of Home Economics.

All previous methods that could be relied on to kill the micro-organisms also injured the keratin which forms the basis of animal fibers. The new process can be used for sterilizing blankets, clothing, and other wool articles that may come into contact with disease germs. It is also adaptable for removing oils and fats from raw wools and permits degreasing and sterilization in one operation.

When the Nation found itself with a huge cotton surplus, Congress assigned to the Bureau the task of studying means of stimulating the use of cotton in hosiery for women. David H. Young, a well-known, widely experienced textile designer, was called in and a small experimental knitting mill was set up to help develop cotton stockings that could compete with silk in style, sheerness, and other qualities that women want.

By 1941, when silk imports were cut off, 150 designs were ready for release to the trade and now are widely used by the industry. American short-staple cotton is not naturally strong, smooth, or elastic enough for sheer, lustrous, shape-retaining stockings and

so experiments are being made with chemical treatments and knitting designs to improve these qualities. The work on elasticity has led to other promising experiments to develop cotton fabrics as a wartime substitute for yarns with rubber cores.

From the scientific point of view, one of the most striking features of the work in clothing was the use of anthropometry to determine the best means of providing reliable standards for sizes in women's and children's clothing. The state of sizing in these branches of the clothing industry was chaotic. No one knew what size 36 or age 4 meant in the garments put out by different manufacturers. Consumers were bewildered and dissatisfied. Retailers said the value of returned goods in children's clothing alone ran to 10 million dollars a year.

This research investigation struck at the heart of the problem by securing WPA help in actually measuring 150,000 school children and 15,000 women the country over. The necessary measurements were decided on in consultation with anthropometrists and representatives of the trade, and the data collected were statistically analyzed to learn what combination of measurements would prove most reliable in fixing sizes and in constructing garments for each size.

The results showed that age was a very poor guide to sizes for children's clothing. Instead, the use of sizes based on a combination of height and hip measure was recommended. Many leading manufacturers have adopted these sizes. The American Standards Association has established an American Standard of body sizes for boys' garments based on this study and manufacturers of women's garments are giving

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serious consideration to the recommendations that they base their sizes on a combination of height and weight instead of on bust measure. The more difficult problem of shoe sizes is now under study with an effort, as a first step, to devise a practicable instrument for three-dimensional measurements of the human foot.

Clarice L. Scott of the Bureau has made a definite pioneer attempt to use function as the basis of design in women's clothes. When defense and war needs began to draw women into farm, factory, and mechanical work, she set out to develop work clothes for the new jobs. She began by studying the bodily movements and the special protection required by each job. Then she designed coveralls, slacks, coats, or whatever garments would best provide for these.

Scott's 16 designs were promptly adopted by commercial pattern companies and several are being used by manufacturers of ready-made garments. In the previous work on designs for children's clothing the principle of adaptation to the child's actual needs had also been closely followed. Their "self-help" features, intended to develop the youngsters' self-reliance, were an innovation, as was also using open-mesh material in the top of sunsuits so that the sun's rays could reach the skin directly.

A more technical piece of work that was fundamental in a hitherto neglected field was the research concerned with proper types of sizing and their best use for both originally finishing and refinishing various fabrics. In the case of cotton materials the methods developed were to prevent wrinkling and to broaden use. The relation was worked

out between the physical properties of starch pastes and the stiffness of fabrics produced by their use. Exact scientific determinations were also made of the correlation between the "feel" of fabrics and various measurable physical factors.

This pioneering work offered a scientific background for many popular publications. It promoted increased utilization of cotton. The end results, however remote and esoteric they seemed at the start, proved valuable both to commerce and to the general public.

As with food and nutrition, the results of the Bureau's technical studies on textiles and clothing have been popularized in many bulletins, leaflets, and charts. The total distribution is well over 8,000,000 copies.

The economic studies conducted by the Bureau of Home Economics do not come within the scope of this review, but they interlock closely with the results of the laboratory research. As was seen in the case of Stiebeling's work in food economics, they round out the contribution that the Bureau makes to the more efficient utilization of household goods and to the improvement of American homes.

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SECTION X

DAIRYING AND DAIRY PRODUCTS

From time to time dairying and dairy products were subjects of discussion in the annual books issued by the agricultural section of the Patent Office and by early Commissioners of Agriculture. But it was some time before work in this field formally got under way. That took place only after the head of the Department of Agriculture had attained Cabinet rank.

In the Secretary's annual report dated October 26, 1889, the considerable growth of the dairy industry in the United States was noted, and it was announced that a proposal had been made to establish a dairy division in the Bureau of Animal Industry. It was thought necessary to extend the butter and cheese markets. The next report, dated 1890, said that it had so far proved impossible to organize such a division and procure its necessary equipment.

Dairy Division is Created

In his report to the Secretary dated June 30, 1894, Chief Salmon of the Bureau of Animal Industry said that the dairy industry must have immediate attention. He thought that an expert at $2,500 a year with two clerks could do what was required. The Dairy Division was actually established in this Bureau on July 1, 1895, with a chief, an assistant, and two clerks. Its function was to collect and disseminate information on the existing dairy industry of the Nation.

SECTION I

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It now became necessary for the Division itself or cooperatively to investigate the methods of preparation, chemical composition, and keeping qualities of creamery butter, as well as special methods of preparing and packaging of butter for shipment to warm climates. Soon the Division also became interested in recommending methods of curing cheese at low temperatures and in the handling of municipal milk supplies, and it issued a special report on the latter.

The passage by Congress on May 9, 1902, of an act to regulate "renovated" butter charged the Secretary of Agriculture with important and specific duties under its sections 4 and 5. These concerned the manufacture, interstate commerce in, and export of renovated butter. The details were assigned to the Dairy Division, thus giving it impetus for growth.

By 1903 employees of the Dairy Division were busy inspecting plants for making renovated butter, 54,656,800 pounds of the butter having been produced by licensed establishments in the year 1902-03. The operation of the law had not been found detrimental to the creamery butter market as some had anticipated it would. The Division was also procuring butter for the United States Navy at this time, as it had done earlier.

Research Gets Under Way

By 1904 the lines of research the Division intended to pursue were well laid down. They concerned the dairy industry in semiarid and "short-grass" regions, the quality of cold-storage butter, the storage of cheese at different temperatures, the manufacture of soft cheese, the investigation of creamery butter, and certain chemical investigations

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carried on in laboratories of the Bureau of Chemistry and bacteriological studies in the Biochemic Division of the Bureau of Animal Industry.

In 1905 the subjects under investigation or that were soon to be investigated included: The manufacture and storage of butter; the manufacture and storage of cheese; dairying in the South; the manufacture of European varieties of cheese; the handling of city milk supplies; dairy husbandry; ice cream; skim milk cheese; creamery and cheese-factory management; and methods of carrying on the market inspection of dairy products. In 1924 the Division became the Bureau of Dairying by Congressional Act and in 1926 its name was changed to the Bureau of Dairy Industry.

Tubercle Bacilli in Dairy Products

Perhaps an early piece of work in the dairy field not carried on in the Dairy Division should be mentioned here because of its importance and relevance. In 1902 studies were begun in the Division of Animal Pathology under the direction of Theobald Smith, to determine the frequency with which virulent tubercle bacilli occurred in dairy products. Use of the tuberculin test in the nineties had shown tuberculosis to be much more common in dairy cows than had previously been suspected.

The studies revealed that virulent tubercle bacilli were common in all grades of market milk. Further study showed that cream, ice cream, butter, and cheese made from infected milk, invariably contained tubercle bacilli, and that the bacilli remained virulent in milk longer than the time required for the milk, through decomposition, to become unfit for use as food.

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These studies also revealed that the tubercle bacilli in butter, salted or unsalted, remained alive for months and that they were a source of danger in fresh cheese, although rarely occurring in cured cheese. The foregoing studies led to an official recommendation that, as a protection to public health, all milk should be obtained from dairy herds that had been proved free from tuberculosis by the tuberculin test, or should be pasteurized before it was used as food in any form.

Work on Butter

Early in this century L. A. Rogers, who became one of the country's foremost bacteriologists, and was long in charge of the dairy research laboratories, began the study of butter-making methods. At that time butter was made by ripening cream. The high acidity of the cream was supposed to contribute to the keeping quality of the butter. Yet the stored butter of the day, in 75 percent of the cases, acquired an objectionable fishy flavor and odor which reduced its sale price several cents a pound.

These flavors were assumed to be caused by bacterial activity in the butter while stored, but Dr. Rogers proved them due to an oxidative process which was accelerated by the acidity of the cream from which the butter was made. Hence it was not wise to use highly acid cream in butter making. Therefore Rogers controlled deterioration in stored butter by reducing the acidity of the cream used in making it. Finally he found that butter made from pasteurized, nonacid cream had exceptional keeping qualities.

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Initially Rogers' work was much ridiculed, especially in trade journals. However, Rogers was permitted to demonstrate his method by preparing large quantities of butter for the Navy. His demonstration proved a complete success and general adoption followed. Ultimately the method changed butter-making practice throughout the world.

It is conservatively estimated that the improved methods of butter making which resulted from this research profit the American butter industry alone to the extent of at least $5,000,000 a year. An unearned increment of the work was the valuable information it produced regarding the mechanism of the oxidative deterioration of fats which proved of great assistance in other investigations to be discussed later, and ultimately in effecting the preservation of fatty foods generally.

Important publications by Rogers on this work were: The Influence of Acidity of Cream on the Flavor of Butter, with C. E. Gray, B. A. I., Bulletin 114 (1909); and Fishy Flavor in Butter, B. A. I., Circular 146 (1909).

Work on Milk Pasteurization

The work of S. Henry Ayres and his associates on the bacteriology of milk pasteurization was fundamental in its field. It forms the basis for all sanitary and health regulations governing the handling and pasteurization of milk supplies in cities and towns in the United States today. The publications in which this work was reported have been widely used and have proved of basic importance. In them was presented for the first time an exposition of the scientific principles underlying milk pasteurization.

Pasteurization of milk was first recommended by a noted American health authority in 1875, ten years after Louis Pasteur had found that heating would prevent souring and abnormal fermentation in wine and beer. At first milk was heated secretively and for the sole purpose of preserving it and preventing dealer losses. Gradually objections to the practice were overcome as milk bacteriology and chemistry came to be better known.

Before Ayres' work was undertaken laymen and even physicians were extremely skeptical about the pasteurization of milk. The theory was held that pasteurization was dangerous to human health because it destroyed the lactic-acid-forming organisms in the milk thus promoting the multiplication of putrefactive organisms which in any case are held in check by the lactic-acid groups. On studying the organisms that survived milk pasteurization Ayres found this not to be the case.

Instead, the process of pasteurization merely tended to reproduce the condition of clean, freshly drawn milk. Nor, as had been held previously, was there any difference in the rate of growth of germs in fresh raw and in pasteurized milks. The results of this research definitely removed the objections of physicians to pasteurization. The investigation was the most important single factor leading to the development of modern milk-sanitation regulations.

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Bacteria Which Survive Pasteurization, by S. Henry Ayres and William T. Johnson, Jr., Bulletin (1913).

Work on the Hydrogen-ions

An unearned increment of Ayres' work was the valuable information produced concerning the bacterial flora of milk and their varied forms. This proved helpful in many investigations. The pioneering hydrogen-ion investigations of William Mansfield Clark may be mentioned. The work revolutionized large sectors of medical and biological research, and it has innumerable far-reaching industrial applications. Its monetary value has been stupendous.

Clark began work in the Dairy Division in 1910 and was first asked to investigate the chemistry of Swiss cheese. Then Rogers asked him to cooperate in work on the gas production by bacteria of the colonaerogenes group. By 1914, this resulted in methods of differentiating such organisms, thus laying the foundation for classifying a group of bacteria of great sanitary significance. It became possible for the first time to distinguish the fecal members of the group from closely related species which did not inhabit the intestines.

While at work on these problems Clark time after time met questions about the meaning of titrable acidity and the significance of "acid" or "alkaline" reactions. This led him to the classic paper of S. P. L. Sorensen on the hydrogen-electrode method of measuring hydrogen-ion concentration, and the work discussed above followed. His own first paper on the subject concerned the reaction of cow's milk, modified

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Clark's original interest was the effect of acid on the growth of bacteria. At that time it was customary to measure the acid in bacterial preparations by titration, though it was known that this method measured the quantity, not the intensity of the acid present, and that some acids were stronger than others. Physical chemists were already aware that the tendency of an acid to dissociate in solution, that is, of its constituent components to hold themselves apart as units, could be measured by determining the concentration of hydrogen-ions in the solution.

This value was of greater significance than that determined by titration methods. Clark pointed out that the checking of bacterial growth in any kind of medium was due to acid intensity or hydrogen-ion concentration, not to mere titratable acidity. Thus a few tenths of 1 percent of hydrochloric acid, which dissociates strongly, would have the same effect on bacteria as a 20 percent solution of a weaker acid like citric. Clark next developed accurate methods for measuring hydrogen-ion concentration and published a book on the subject which became standard throughout the world.

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It is true to say that Clark essentially founded a new science. The ramifications were almost incredible. He also synthesized a series of indicators (chemical substances which change color as they go from

acid to alkali, or vice versa) by which accurate hydrogen-ion determinations could be made rapidly. This all seems rather impractical and abstract, but today the laundry industry controls the reaction of its wash waters and rinse waters by means of indicators Clark developed in the Department of Agriculture. Clark's work is used in all of the following industrial and other processes, and more:

Water purification; work on the erosion of metals; paper manufacture; the digestion of sewage for disposal; the disposal of industrial wastes; the manufacture and refining of beet and cane sugars; the manufacture of dyes and pigments; the manufacture of corn sugar, glucose, and candy; textile processing; clay casting; leather tanning; differential ore flotation; electro-plating and electro-typing; chemical analysis, the fermentation industries; the making of fruit jellies, and of flour, dough, bread, and crackers; the manufacture of milk products and the control of milk bacteria; canning foods; analyzing soils; the manufacture of pharmaceutical preparations. It is also used in clinical pathology.

Clark's important paper which signalized the abandonment of the old titration method of adjusting reactions of culture media and introduced the now universal practice of adjusting the pH value appeared in the Journal of Infectious Diseases during 1915. His well-known book, The Determination of Hydrogen-Ions first appeared in 1920, in which year he left the Department and went to the Hygienic Laboratory. For a number of years he has headed the Department of Physiological Chemistry at Johns Hopkins University. In 1920 Clark began to publish

papers on reduction potentials; this work led him later to study the oxidation-reduction systems of the human body and proved to be of great importance.

Other Research

Other important research carried on thereafter will be mentioned in rough chronological order though too briefly to do it full justice. In 1914, L. S. Palmer began work on carotene and other milk pigments, and his many contributions to dairy science in the next 25 years won him the Borden award in chemistry in 1939. In this year Rogers himself published a paper on the preparation of dried bacterial cultures by the freezing-high-vacuum method; it was so thoroughly forgotten later that someone else got a patent on Rogers' method which is now widely used for the preservation of cultures and other biological material.

Swiss Cheese

A year or so later C. F. Doane and H. E. Eldridge published some work on the use of pure lactobacilli cultures in making Swiss cheese. This initiated the work on the bacteriology of Swiss cheese which has resulted in the use by domestic makers of three bacterial cultures, and such control of the process as has greatly improved the domestic product.

The manufacture of nearly all milk products depends on the control of bacterial growth. Properly to exercise this control one must know the conditions governing the growth, activities, and death rate of the

bacteria. In this instance the investigations established the fact that the quality of Swiss cheese depends largely on the growth, at proper rate and in definite sequence, of at least three bacterial species.

To help makers of Swiss cheese produce a high-grade product the Bureau of Dairy Industry now supplies them with cultures of these bacteria as starters. About 50,000,000 pounds of this cheese is made annually in the United States, and an increasing percentage is produced by culture methods. As the culture cheese usually sells for more than the non-culture cheese, this research alone has a potential value of $1,000,000 a year to the dairy industry, estimated on a 2-cent-a-pound increase in value.

Fermentation Process for Citric Acid and Propionic Acid

In 1917 appeared J. N. Currie's paper on the citric acid fermentation of the mold, *Aspergillus niger*. This led to the first commercial fermentation by a mold. Currie's culture and process were used to ferment cane sugar into citric acid on so large a scale that the citric acid formerly made from lemons and limes in Italy and Greece, and imported here, was replaced by a purely domestic product.

In 1922 began a series of papers by James M. Sherman, R. H. Shaw, and E. O. Whittier on propionic acid fermentation. These give in detail the course of fermentation by which propionic acid may be produced commercially by the action of bacteria. The process mentioned is covered by a number of public-service patents. Salts of propionic acid are used principally as preservatives against molds.

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Bacteria of the Normal Udder

In 1918, papers by Alice C. Evans on the bacteria of the normal udder began to appear. They ultimately established a close resemblance between the organism causing contagious abortion in cows with that which causes Malta or undulant fever in human beings. This was a discovery of great significance and gave Miss Evans a world-wide reputation. It forged an important link connecting the disease of cattle and goats with that of man.

Casein Studies

In 1919 there were papers by Clark and associates showing how the precipitation of casein could be obtained in small, firm granules from which ash constituents could be readily washed, by control of the pH and temperature during the process. The application of these principles to the commercial manufacture of casein has made possible the large-scale preparation of a very pure product.

Bureau scientists have since devoted much study to milk casein. They established a method of grading casein according to its paper-coating quality, and improved the manufacturing process. This resulted in far greater domestic production and less reliance on imports.

Roquefort or Blue-Mold Cheese

In 1921, K. J. Matheson published a paper on the manufacture of Roquefort cheese from cow's milk. This was the result of a long investigation begun in cooperation with the Storrs Experiment Station in

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Connecticut, which established the biological activities involved in the ripening of blue-mold cheese, the technique of making such cheese from cow's milk, and the conditions essential to proper ripening. All the blue-mold cheese now made in this country comes from what is essentially the Matheson process.

Why Milk Fat Spoils

Around 1924 a long series of papers by George E. Holm, George R. Greenbank, and others began to be published on the oxidation of fats and the relationship between such oxidation and changes in the flavor of butter, milk powder, and other fat-containing products. These investigations were initially in the field of pure research but resulted in many practical applications to a wide variety of fats and oils.

In 1942, Dr. Holm received the Borden Award in chemistry for this work. It led to a better understanding than had ever been had of why fats and oils spoil, and the methods needed to prevent such spoilage. As a result of these investigations improved methods of handling and preserving whole-milk powder were developed at a time when its shipment to our Allies was an urgent wartime necessity.

Holm's work on milk proteins is also outstanding and he has done fruitful studies on the minor constituents of milk which again are in the field of basic research.

Undesirable Flavors and Odors in Milk

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Why Milk Gets Rancid

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Bacteriophage Viruses and Gases in Milk

A common cause of much milk spoilage began to be studied by Bureau scientists more than 20 years ago. Millions of gallons of milk are ruined

from the fluid-milk market every year because of undesirable feed flavors and odors. The acceptance of such milk would have a detrimental effect on consumption for the quantity of milk consumed depends partly on its palatability. J. A. Gamble and Ernest Kelly found that the flavors and odors from feeds and weeds eaten by cows pass through their bodies to the milk in the udder. They are not, as was formerly believed, absorbed by the milk directly from the air.

Further work by C. J. Babcock showed that some feeds and weeds continue to impart their characteristic flavor to milk for much longer periods than others. Garlic is one of the most troublesome weeds. It flavors the milk 1 minute after the cow has eaten it, and this flavor takes about 7 hours to disappear entirely. Other feeds impart their flavor to milk for only an hour or two. Practical feeding practices have been evolved which enable dairymen to use certain nutritious but highly flavored feeds, like silage, turnips, cabbage, kale, and sugar beets, without producing abnormally flavored milk.

Such feeds are given the cows immediately after milking so that their flavor passes off before the next milking. If all dairymen observed the recommended feeding practices it would add many millions of dollars a year to their aggregate income. Strong garlic flavor, however, can be found in milk drawn 2 minutes after cows have merely inhaled the odor for 10 minutes, indicating that milk within the cow acquires the odor via the animal's inhalations. As the time interval between eating the garlic and milking increases the effect decreases and it practically disappears after 90 minutes. The only practical way to prevent garlic flavor and odor in milk is to prevent the cows from eating the plant.

Making Lactic Acid by Fermentation

In 1928 there began to appear the first of a series of papers by Earl O. Whittier and L. A. Rogers on lactic fermentation. The investigations showed that if such fermentation is properly conducted it is exceptionally efficient and may be used to convert the milk sugar in cheese or casein whey into a marketable product. As a direct result a large-scale commercial lactic-acid enterprise was established. Now that the supplies of cane and corn sugar for fermentation are restricted the enterprise will probably be extended. It is based on fermenting casein whey to make the lactic acid.

Physiology of Milk Secretion

Physiological studies of milk secretion have long been carried on by Bureau scientists and in 1926 Walter W. Swett and associates showed by experiment that secretion is continuous and not, as the textbooks then stated, confined to the brief period during milking. This was ascertained by milking udders after they had been removed from cows at slaughter and comparing the quantity of milk so obtained with that obtained at corresponding milkings before death.

Results of this investigation completely revised many ideas about milk secretion and provided a basis for much work on the physiology of lactation that has since been conducted. Incidentally, among the hundreds of udders studied no case of a cancerous growth has ever been found. It almost appears as though the cow's milk-secreting organ is immune to cancer.

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Genetics of Dairy Cattle

The dairy scientists began the task of developing a scientific and practical breeding program for dairy cattle as early as 1918. At that time one school of thought advocated line breeding, a second close inbreeding, and a third advocated the mating of unrelated animals only. No basis of scientific principles for guidance existed for no actual experimental work had been carried on under controlled conditions to solve the problems about which so many had opinions. Experimental breeding herds were therefore established. Work with them has continued for years.

As a result, it was concluded that the most successful sire is one homozygous or pure in his genetic make-up for factors that govern the transmission of high milk and butterfat production. The best way to measure a sire's transmitting ability was through study of the production records of his daughters. If the sire demonstrated ability to beget daughters which were better producers than their dams, this indicated homozygosity in his genetic make-up for high-production factors.

Out of this prolonged study came the so-called proved-sire systems of breeding. In this, attention is centered on the use of sires of proved ability as described above. For more than 20 years sires have been selected on this basis at various field stations, and remarkable progress has been made in developing strains or herds that approach purity in their inheritance for high production. Such sires will transmit high production to their offspring, whether related or unrelated to him, hence the selection of sires need not be confined to the same family.

Breeding of Dairy Cattle

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Farmers and breeders now have a lively interest in proved sires. Because there are few great sires much work has also been done toward prolonging the active lives of proved sires. Their superior germ plasm has also been perpetuated in various ways. The factors involved in artificial insemination and the preservation of bull spermatozoa have been studied carefully. So far, viability of sperm cells have been maintained for 62 hours under laboratory conditions, and a few bulls have been kept fertile until 16 years of age though bulls do not usually breed beyond 10 years.

From the time dairy cattle were first placed at the Beltsville station in 1912 an inbreeding experiment has been in progress under the direction of T. E. Woodward and R. R. Graves. It was concluded in 1942. The plan was to mate successive generations of daughters with their sire until the sire became impotent, then to mate these animals with the inbred son of the previous sire for successive generations and so on with succeeding sires. Probably no experimental dairy herd in the world has been so intensely inbred. Eight Holstein sires have been used in the 30 years. A progress report was published in 1933.

The following facts have been brought out. Moderate inbreeding (less than 25 percent measured by Wright's formula) was not definitely harmful in any way. More intensive inbreeding increased the services required for conception, greatly reduced the birth weight of calves, impaired their vigor, retarded their growth, reduced their mature size, and lowered their production of milk and butterfat. This investigation

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showed that with the animals used in this work close inbreeding was carried on for a surprising length of time before any noticeable bad effects occurred. For a number of generations the production held up well and there was a noticeable uniformity of type. When the undesirable effects did appear one out-cross was enough to wipe out the detrimental effects phenotypically.

In July 1921, M. H. Fohrman, and in 1927, J. R. Dawson, came into the Division and both have been closely associated with the breeding projects. They have published numerous papers on the results of their experiments, including early work on correction factors; methods of taking uniform pictures of livestock for experimental purposes; age and other factors influencing the fertility of sires, and methods of evaluating the inheritance of sires.

F. W. Miller was also associated with the breeding project at Beltsville and did some of the pioneer investigational work in this country on artificial insemination; the factors influencing the viability of sperm cells; the influence of diet and exercise on fertility, and the effect in overcoming sterility of the transplanting of gonadal tissue. Both Miller and Fohrman collaborated in studies of the results of the segregation of a herd infected with Bang's disease.

In 1935 a germ plasm survey was conducted in order to supply material for the 1936 Yearbook of Agriculture. The milk-production-record information on nearly a thousand herds of dairy cattle was studied in the Division of Dairy Cattle Breeding, Feeding, and Management Investigations.

This was the first application of a working plan of herd analysis to determine the quality of germ plasm in the herd through a study of all males and females that had contributed to the development of that germ plasm. This method of herd analysis is now being used in many herds with a suitable production-record program, and is helpful in creating a better understanding of the laws of heredity as they apply to the breeding of dairy cattle.

After the scientists had studied the genetics of dairy cattle, some means had to be found of explaining the principles of Mendelian inheritanse to lay breeders, as oral presentation usually proved confusing. R. R. Graves therefore designed his herediscope demonstration of dairy-cattle improvement, first reported in the Journal of Heredity for September 1929. The device gave impetus to the teaching of the principles involved and has been widely used.

Nutrition of Dairy Cattle

Along with such study has gone research on feeds and feeding methods of practical value on the effects of vitamins and minerals in the rations of dairy animals, and on the palatability and nutritive value of various roughages. Some of this work on dairy-herd nutrition is still in the realm of pure research, but it offers interesting possibilities. For instance, there are as yet unidentified growth-promoting factors in cows' milk that may be derived from the feed, and evidence has been adduced that certain plants contain gonad-stimulating substances. Efforts have

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been made to trace dietary constituents from the feed trough through the blood and into the milk.

Research in the field of pure science must be performed faithfully and continuously or science cannot progress. Some of the work deals with refinements of methods which have made experimentation both more reliable and less cumbersome, and the conclusions drawn, therefore, more accurate. Much has been discovered regarding the mineral, energy, protein, and vitamin A requirements of dairy cattle. Other tedious studies have greatly increased our knowledge of the composition and chemical reactions of casein and other proteins, and useful tools in the study of wool processing and the manufacture of protein plastics and synthetic protein fibers have been developed.

The first practicable feeding standards for dairy cattle were formulated in 1864, before dairy work was undertaken in the Department. These have since been refined by a number of investigators. For all these years it has been tacitly assumed that if cows were fed in a way to meet the requirements of an accepted standard they were at the same time being fed in the most profitable way. Until recently, investigations have dealt with the physiological response of cows to different kinds and quantities of feeds, little attention being paid to the economics of feeding.

In 1936 a cooperative project with the Bureau of Agricultural Economics and 10 State experiment stations was begun for the purpose of finding out how heavily it pays to feed cows at various prices for the feed and product, in other words, to find out at what level of

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feeding the net returns reach the highest point. The yearly milk and feed records for 454 cows were obtained, making this the largest controlled feeding experiment ever conducted with dairy cows in the United States.

Carefully balanced groups of cows were fed at different levels ranging from no grain at all to as much as they would eat. Every increase in feed resulted in the production of more milk but this extra production became less and less for each increase in feed as the feeding was pushed to higher levels. By comparing the value of the additional milk with the cost of the additional feed, it was possible to determine the level of feeding above which it did not pay to go. The most profitable level of feeding depends upon the relative prices of forage, grain, and milk, and may range all the way from no grain at all, where the forage and milk are cheap and the grain is dear, to all the grain cows will eat, where the feed is cheap and the price of milk is high.

Cows fed according to an accepted standard for an entire year generally became thin in flesh and failed to produce large quantities of milk. Standard feeding is well below the most profitable rate over the greater part of the United States. As a result of this investigation, ideas about feeding must be revised to take into account the prices of the feed and product, and less attention must be paid to feeding standards.

T. E. Woodward and J. B. Shepherd made hundreds of lots of experimental silage and demonstrated that excess moisture is detrimental to the quality of silage as well as destructive to the silo. They showed that by proper attention to moisture content and the expulsion and exclusion of air from

the silage the trouble and expense of using such preservatives as molasses and acids could be avoided. These investigations, therefore, gave results of great economic importance.

The carrying-capacity investigations at the Huntley Station and later at the Utah Station (coop.) had a marked influence on the greater use of irrigated pastures throughout the Rocky Mountain region. The results of the experiments were published in Technical Bulletin 116, Dairy Work at the Huntley Field Station, Huntley, Montana, 1918-1927, by T. W. Moseley, Duncan Steuart, and R. R. Graves.

Results of other basic investigations on the value of high-quality roughage for dairy cattle followed. The results of an experiment comparing the feeding value for milk production of pasture grasses when grazed, when fed green, and when fed as hay or silage, were published in 1933. (Technical Bulletin 381, by R. R. Graves, J. R. Dawson, D. V. Kopland, and T. W. Moseley.) This was one of the first comprehensive experiments carried on in this country to show the feeding value of early cut grass for dairy cattle. This was followed in 1938 by a report of an experiment on the relative value for milk production of hay and silage made from immature pasture herbage by R. R. Graves, J. R. Dawson, and D. V. Kopland. (Technical Bulletin 649.)

In another experiment by R. R. Graves, J. R. Dawson, D. V. Kopland, A. L. Watt, and A. G. Van Horn, carried on at several of the field stations and published as Technical Bulletin 610, cows were fed exclusively on alfalfa hay for entire lactation periods and some individuals were fed through three consecutive lactations. Fifteen Holstein cows made 24

production records with the remarkable average of 11,125 pounds of milk and 390 pounds of butterfat (calculated to a mature basis). This was 57 percent as much milk and 60 percent as much butterfat as the same cows produced when fed full-grain rations in addition to alfalfa hay and silage.

The feeding value of Sudan hay when cut at three different stages of maturity was studied at the Woodward (Okla.) Station by J. R. Dawson, R. R. Graves, and A. G. Van Horn and published as Technical Bulletin 352. Likewise, the comparative feeding value of alfalfa hay when cut at three different stages of maturity was shown by an experiment at the Huntley Station and published as Technical Bulletin 789, by J. R. Dawson, D. V. Kopland, and R. R. Graves. This last was the first long-time feeding experiment of this nature where producing dairy cows were used to measure the comparative feeding value of the hays. In both of these experiments hay cut at early stages of maturity was markedly superior in all respects to hay cut at the more mature stages, and there was no decrease in per acre yields.

Work on Ice Cream

The Bureau's researches have led to great improvement in the quality of ice cream during the last decade. In the beginning, commercial ice cream contained a low proportion of valuable milk solids and it was rarely made from pasteurized milk and cream. The research workers early found that most persons prefer ice cream rich in butterfat, sugar, and milk-solids-not-fat. However, when manufacturers attempted to increase the milk-solids

production records with the remarkable average of 11,169 pounds of milk and 391 pounds of butterfat (calculated to a mature basis). This was 97 percent as much milk and 80 percent as much butterfat as the same cows produced when fed full-grain rations in addition to alfalfa hay and silage.

The feeding value of timothy hay when cut at three different stages of maturity was studied at the Beltsville (Md.) Station by J. B. Shepherd, R. R. Graves, and A. G. Van Horn and published as Technical Bulletin 166. Likewise, the comparative feeding value of alfalfa hay when cut at three different stages of maturity was shown by an experiment at the Huntley Station and published as Technical Bulletin 799, by J. B. Shepherd, H. T. Copland, and R. R. Graves. This last was the first large-scale feeding experiment of this nature where producing dairy cows were used to measure the comparative feeding value of the hays. In both of these experiments hay cut at early stages of maturity was markedly superior in all respects to hay cut at the more mature stages, and there was no decrease in per acre yields.

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content of their product it tended to become gritty or sandy in texture. This tendency was found to be due to excessive milk sugar, which crystallized when the ice cream was subjected to varying temperatures in the hardening rooms or in dealers' cabinets.

Between 1933 and 1936 papers appeared by Alan Leighton, Byron H. Webb, and Owen E. Williams showing that the viscosity of skim milk can be reduced by adding cane sugar; then on concentration the lactose, or milk sugar, may be crystallized out and removed. Commercial methods were developed for removing a large percentage of the milk sugar from skim milk. The resulting condensed skim milk, low in milk sugar content, could then be used to increase the milk solids in ice cream without producing sandiness. If, as a result of this work, the average milk-solids-not-fat content of ice cream could be raised only 1 percent, that would provide an additional market for more than 1,500,000,000 pounds of skim milk annually.

Studies of Cream Viscosity

Studies of cream viscosity announced in 1931 indicated how it could be controlled. For consumers judge the quality of cream mainly by its viscosity or body, a quality they associate with richness. Though butterfat content and temperature are two important factors affecting viscosity, C. J. Babcock found that creams of the same fat content and at the same temperature might vary in viscosity. The butterfat in fresh cream also occurs in individual globules and any factor that affects the clumping of these globules also affects the viscosity. Aging the cream increased both clumping and viscosity; pasteurization lowered both.

content of their product it tended to become gritty or sandy in texture. This tendency was found to be due to excessive milk sugar, which crystallized when the ice cream was subjected to varying temperatures in the hardening rooms or in dealers' cabinets.

Between 1933 and 1936 papers appeared by Alan Leighton, Byron H. Webb, and Owen R. Williams showing that the viscosity of skim milk can be reduced by adding some sugar; then on concentration the lactose, or milk sugar, may be crystallized out and removed. Commercial methods were developed for removing a large percentage of the milk sugar from skim milk. The resulting condensed skim milk, low in milk sugar content, could then be used to increase the milk solids in ice cream without producing sandiness. If, as a result of this work, the average milk-solids-not-fat content of ice cream could be raised only 1 percent, that would provide an additional outlet for more than 1,500,000,000 pounds of skim milk annually.

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Viscosity is also affected by the methods of handling and storing cream. The best way to increase viscosity is to store the milk at a low temperature for 12 hours before separation, then lower the temperature at which separation occurs. Homogenization also increase viscosity, freezing lowers it, and viscosity increases as the percentage of solids-not-fat increases.

Other Valuable Scientific Findings

In 1931 there appeared the first of a series of papers by Harold R. Curran giving the results of investigations on the effects of heat, ultraviolet light, and other physical agents on spores. These investigations brought out many new data on factors that determine the viability of bacterial spores and the means by which their resistance may be overcome.

On March 15, 1930 the first recovery of a fertilized ovum from the fallopian tubes of a cow threw light on questions concerned with the time of ovulation, the time of fertilization, the conditions favorable to fertilization and the characteristics of the ovum, all vitally important to the biologist, the geneticist, and the cattle breeder. This work also provided a basis for the preparation of a valuable education motion picture, "In the Beginning," which has been in great demand throughout the United States.

A new test for the prompt detection of mastitis streptococci was announced in 1936. It was called the Hotis test, after its originator, H. P. Hotis, who died soon after conducting most of the experimental work.

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It offered a ready means of diagnosing this troublesome and costly disease, the quick detection of which is always urgent.

A detailed study of females twin-born with male calves revealed certain characteristics which may be found in the living animal that may be relied upon with reasonable certainty in determining which of such animals will prove to be freemartins and incapable of reproduction.

Packaged and Bel Paese-type Cheese

In 1932, a paper by Rogers on ripening cheese in sealed packages appeared. This was the first successful method for providing a satisfactory retail package for natural cheese. The cheese was canned in a tin containing a special valve Rogers designed. It has been used successfully for packaging both Cheddar and Swiss cheese, including cheese already sliced in sandwich size. The process expands the market for cheese by enabling consumers to purchase as needed a well-ripened, palatable cheese of uniform quality. It also pleases the trade because it makes possible brand labels on small units.

In 1936 Bureau scientists announced their new process for manufacturing Bel Paese-type cheese, a soft, very white variety of European origin. The copyright name was held by the Italian manufacturer who originated the cheese, but the type could now be made in this country by following directions issued at the time. The product was of uniformly high quality.

Cheese Whey and Canned Soup

About the same time it was announced that cheese whey could be used to increase the food value of canned vegetable soups and of fruit-flavored

whips, thus affording housewives a convenient method of adding milk constituents to the diet and at the same time providing a new outlet for a dairy-industry byproduct. Whey contains half the food solids of milk and hence has exceptional nutritive properties.

Whey, whey powder, or whey cream can be used in place of whole milk or cream to enrich vegetable soups; they also cause less difficulty with coagulation. Whey can be combined with highly acid juice of oranges, grapefruit, strawberries, loganberries, and so on, and the products canned for use in salad or desserts.

Utilization of Dairy Byproducts

The remaining dairy research to be considered is concerned in the main with commercial utilization of byproducts, the more than 6,000,000,000 pounds of milk solids contained in the skim milk, buttermilk and whey produced as byproducts in the manufacture of cream, butter, and cheese each year. These byproducts are often wasted or utilized so inefficiently that returns are small.

Several years ago Bureau scientists discovered that certain difficulties in condensing skim milk to a point at which its natural acidity would act as a preservative could be overcome by using certain high-acid-producing culture. About 75,000,000 pounds of skim milk are now converted into concentrated sour skim milk annually. This can be stored indefinitely and transported long distances as feed for poultry and hogs. Methods have also been found of so manufacturing skim milk powder as to increase its desirable effects when incorporated into bread and ice cream.

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Lactic acid, which was first identified in sour milk nearly 160 years ago, and is widely used in the leather and textile industries, was made commercially from milk for the first time in 1936 as a result of work by Department scientists. They developed methods for making lactic acid and related chemicals from whey, and also of concentrating the acid to a greater degree than hitherto. A large dairy organization promptly took up the method and adapted it for large-scale production of lactic acid and calcium lactate on a commercial basis.

In 1939, Lee T. Smith and H. V. Claborn announced the perfection of a process for converting lactic acid into a somewhat transparent, flexible substance, known to chemists as polymethylacrylate. This substance is closely related to the so-called organic glass made synthetically for use in highway reflectors, and can be combined with organic glass to make a superior molding material. It can be used as a supporting material, as in motor mountings, and also to coat fabrics and paper to make them water-, oil-, and gas-resistant. In 1940, Claborn produced and patented a somewhat similar polyacrylate devoid of lactic acid, a commercial byproduct from oats.

About the same time Stephen P. Gould and Earl O. Whittier announced the production from casein of a synthetic fiber having the appearance of wool. The process used was similar to that of making viscose rayon from cellulose and eight public-service patents were obtained. This resembled but did not duplicate a previously announced Italian process. Except for a lower sulfur content the product was almost identical with wool chemically. It could be made from skim milk, 4,000 pounds being required

to produce 100 pounds of casein fiber.

The Gould-Whitzler public-service patent makes it unnecessary for domestic manufacturers to pay royalties on this process. In 1940, 4,000,000 pounds of casein fiber were produced in this country and production has increased rapidly.

In 1941, the Bureau scientists announced an improved method of evaporating milk to a greater total-solids content than ever before. This would have stepped the nutritive value up 25 percent at a time when shipping space to Britain was at a premium, and the British wanted American evaporated milk in huge quantities. But, before commercial evaporating plants could shift to this method, shipping space became so short that the British wanted whole-milk powder. The scientists were ready to suggest methods for producing and packaging it, as a result of earlier research. So considerable quantities of whole-milk powder of acceptable quality were shipped to our allies in 1942.

In 1942, Paul D. Watson announced the development of a lacquer substitute for the tin coating used on cans made to hold evaporated and condensed milk and to ship fluid milk and cream. The lacquer substitute, on which he filed application for a public-service patent, was made chiefly from lactic acid derived from milk. Thus, the cow may furnish or replace critical materials like tin. The Bureau has cooperated with a number of commercial companies in further development and use of the method.

Research in Wartime

Since 1910 this Bureau's appropriation has averaged about a half million dollars a year and has never exceeded $796,990, compared with the

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Research in Feeding

Since 1929 this Bureau's appropriations has averaged about a half million dollars a year and has never exceeded $750,795, compared with the

$2,000,000,000 farm income from dairy products. Evidently, the Bureau's research activities have been well worth the price.

The outbreak of war brought a speed-up continuation of many research projects already under way, as well as the initiation of new studies as direct aids to the war. Aside from the shift of research to a war basis, most of the technical men in the Bureau acted as advisers or consultants to other branches of the Government seeking specialized wartime information.

The Government's program for expanded milk production accelerated the Bureau's work on the relationship between feeding and milk output, and the finding and loaning of good bulls. Successful efforts have been made at the same time to improve the quality of the cheese purchased for lend-lease export. Bureau specialists move from factory to factory, with a trailer laboratory, to help the cheese makers. A survey was undertaken to find how much vitamin A is obtained from butter produced in different regions and in different seasons, so that feeding practices may be recommended to increase the milk vitamin A content.

The possibility that fats and oils might be in short supply led to increased study of the relative nutritive value of various fats, especially corn, soybean, coconut, and cottonseed oils, and butterfat. In the effort to help provide or replace strategic and critical raw materials, the Bureau's technicians began to study the replacement of cane sugar in ice cream with other sugars, the composition and chemical reactions of different proteins, the production of alcohol from whey, substitutes for molasses in making grass silage, the production of sirup

from milk sugar, the use of plastics to replace stainless steel in cream separators.

Finally, as a solution of the War Department's problem of providing butter for use in tropical climates, the dairy industry was advised on the production, packaging, storage, and shipment of canned butter oil. Assistance was also rendered the Army in getting an adequate milk supply for certain camps.

The Bureau of Dairy Industry has had a relatively short but a very active and productive career. War found it ready, as it had been at peace, to serve the dairy industry and the Nation.

SECTION XI

AGRICULTURAL ENGINEERING

Early Irrigation, Drainage, and Engineering Investigations

Early irrigation, drainage, and engineering investigations formally began in 1898 with irrigation studies in the Office of Experiment Stations; land-drainage investigations followed in 1902. In 1915 the work went to the Office of Public Roads along with certain farm architectural studies that had been carried on by the Office of Farm Management.

In his annual report for 1890 Jeremiah Rusk, Secretary of Agriculture, noted a Congressional appropriation of $20,000 for the investigation of the proper location of artesian wells to irrigate semiarid regions, April 4, 1890. This comprised the States, or parts, of North and South Dakota, Montana, Wyoming, Colorado, New Mexico, Texas, Nebraska, Kansas, and Oklahoma. Edwin S. Nettleton was appointed supervising engineer and Robert Hay geologist. An Office of Irrigation Inquiry was set up later under special agent R. J. Hinton to make general reports on irrigation, as a result of an additional appropriation of $40,000 and the report on artesian-well investigation.

In 1891 Secretary Rusk said that Congress had appropriated in all $70,000 for the investigation of artesian wells, underflow waters, and

the sources and availability of irrigation. Field work was continued. A report of 300 pages existed, but there were no funds to publish it. Howard Miller was then serving unpaid as a special agent to study certain Colorado and Kansas wells.

The growth of irrigation was noted in the annual report for 1892, but the investigations were suspended. In 1893 the work consisted in collecting and abstracting State and Territorial Laws governing water rights. In 1894-5, Charles W. Irish was in charge, then these investigations lapsed for a while.

In his report for 1897, James Wilson, Secretary of Agriculture, made note of another $10,000 appropriation for irrigation investigations. No separate division was set up this time, but the work was put into the Office of Experiment Stations. A crisis was said to exist in agricultural communities dependent on irrigation; numerous irrigation districts were being established and settled by thousands of farmers; local laws and institutions were unsatisfactory, while correct irrigation practice was not observed and indeed remained to be fully determined.

Elwood Mead, State engineer of Wyoming, was consultant and a general conference was held on the subject. It was decided to assemble information on irrigation laws, institutions, and practices, though in 1898 the work moved slowly with the inadequate help that could be obtained in this new field of science. More detailed investigation was needed and, in 1899, Congress increased the appropriations. An office of Irrigation Investigations was established in Cheyenne with Mead in charge.

The main studies in 1900 dealt with the basic principles of the use of water in agriculture and were carried on in California, Utah, and Colorado; investigations of sediment in canals and reservoirs now formed part of the work. In 1901 it was suggested that the Government should undertake extensive irrigation works, damming large rivers and so on, making drainage investigations, and reclaiming alkali soils. A laboratory of soil physics now existed.

In 1902 Secretary Wilson mentioned in his report the importance of agricultural engineering as related to irrigation and stated that the capital invested in the manufacture of agricultural machinery had increased from $60,000,000 to $157,000,000 in the past 20 years. The value of the product had doubled. Changes in agricultural technology had wrought a revolution, but the Department could offer no expert advice on the subject. Secretary Wilson thought it should enter this field, investigate the lay-out of farms, the arrangement of farm buildings, drains, farm water supply, farm sewage disposal, barn-ventilation systems, and the design of farm buildings.

In 1902 agricultural engineering investigations of a sort got under way in the Office of Experiment Stations on the lay-out of farms, drainage, and laboratory and field tests of farm implements and machinery, and in 1903 it was recommended that $10,000 be expended for such purposes. In 1904 the reports contained a review of State work in agricultural engineering, with a further plea for Federal funds, because $100,000,000 worth of farm machinery was now sold annually, one-half of it going to those who could neither select nor use it wisely.

Drainage of agricultural land had progressed beyond the individual farm; cooperative efforts of many farmers were necessary to obtain adequate outlets. Machinery for digging large ditches was available, but landowners were unable to proceed with these drainage works because of lack of technical skill and knowledge. The Department, therefore, was called upon for assistance in planning and organizing many of the early cooperative drainage districts. On February 23, 1943, agricultural engineering research was transferred from the Bureau of Agricultural Chemistry and Engineering to the Bureau of Plant Industry, which then became the Bureau of Plant Industry, Soils, and Agricultural Engineering.

In 1905 cooperative projects in agricultural engineering were carried on with the agricultural colleges and experiment stations, and it was suggested that Irrigation and Drainage Investigations be called Rural Engineering. On October 15, 1907 drainage investigations were separated from irrigation studies in the Department.

In 1911 more than 700,000 acres were seeded to rice alone, all irrigated, and growers received $18,000,000 for the rice produced. It was also stated that the worth of Arkansas prairie lands went up from $5 to $6 to $50 to $90 an acre due to irrigation. It was stated that if drainage were carried out where needed, in line with facts Department investigation had unearthed, the results would increase land values $1,500,000,000, and annual income $250,000,000.

About 1913 S. H. McCrory became chief of drainage investigations and on April 1, 1915, drainage and irrigation investigations went to the unit which became the Office of Public Roads and Rural Engineering on the

following July 1. During this time aid was given the States in setting up water laws and in educating farmers in the more economical use of irrigation water. At the same date certain farm architectural work previously carried on in the Bureau of Plant Industry, Office of Experiment Stations, and the Office of Farm Management went to Public Roads and became a rural engineering project.

Plans were then made to put all rural engineering work into one Division of the Office of Rural Engineering with H. B. McCormick as chief as of July 1, 1915. The Division first studied the farm domestic water supply, farm sewage disposal, the construction of farm buildings, and farm machinery and equipment. Questions came in on a wide variety of farm mechanical problems.

In 1923 the ventilation of dairy barns occupied much attention, but a meeting in March of that year considered the use of electricity in agriculture and such use of power was nominated as a proper subject for Federal research. The investigations also concerned farm plumbing, the use of concrete in building, and the use of motortrucks and tractors. In 1925 the annual report stated that farm power cost $3,000,000,000 annually and a bulletin was issued on the service of power to farms.

In 1927 the Division of Agricultural Engineering reported work on irrigation, drainage, farm-land development, mechanical farm equipment, and farm structures. Its engineers had developed implements to reduce corn borer hazards, machines for improving the distribution of fertilizer, devices for mounting in airplanes for dusting cotton (now widely used),

seed-cotton driers, and methods for cleaning drainage and irrigation ditches.

The Division became the Bureau of Agricultural Engineering July 1, 1931, with S. H. McCrory, chief. It comprised work on irrigation, drainage, farm-land development, farm-machinery investigations, and farm structures as before. It became part of the Bureau of Agricultural Chemistry and Engineering in 1939.

A typical example of this early work may be found in Department Bulletin 512, issued April 5, 1917, on the Prevention of Erosion of Farm Lands by Terracing, by C. E. Ramser, a drainage engineer. Before this investigation no scientific data existed upon which to base the design of terraces to prevent soil erosion. Terracing was carried on by rule of thumb. The bulletin mentioned gives the general engineering principles underlying the design and construction of broad-based terraces and the rules to be followed to ensure their proper functioning.

During the decade before 1933 some 15,000,000 acres had been terraced on more than 300,000 farms. In 1933 it was estimated that this resulted in an average increase of $6 per acre in the value of the land, or a total value of at least $90,000,000 which may be attributed to the investigation reported in Bulletin 512. More is said about these early investigations in the fields of drainage and irrigation in another section of this present publication.

Varied Research Accomplishments

It will prove useful to give a brief review of important research findings by Department scientists in the field of agricultural engineering before considering few of these instances in more detail. From the long-time studies of farm buildings four regional farm-building services have been developed, devised to promote uniform building practices on farms. Acceptable building plans have been worked out in cooperation with the State colleges and much duplication of work eliminated. Important studies of comfort factors in farmhouses, those concerned with heating and ventilation for instance, have been carried out and have resulted in new recommendations for the construction and remodeling of farmhouses. The fundamental principles governing the ventilation of dairy barns have also been established.

Grain-storage investigations have led to better methods of holding wheat and other grains on the farm for long periods. This work assumed great importance when the Ever-Normal Granary plan came into existence. The development of scientific methods of storing potatoes was followed by great improvement in the storage structures used for this purpose, which not only tends to prevent loss of potatoes but also makes the storage building more durable.

Engineering work has resulted in better orchard-heating equipment and in improvements of domestic oil burners for household heating. On the other hand important researches have been carried on concerned with the precooling of fruits and vegetables for rail shipment. These have

resulted in large savings to shippers. Improved transportation refrigerating equipment has been designed.

Fundamental work has been carried on concerned with the cause and prevention of dust explosions in threshing machines, flour mills, and elevators. The research in this field over a number of years, resulted in great reductions in the dust-explosion and farm-fire hazards in some branches of agriculture, in many industries based on the processing of farm products and in other industries.

Largely as a result of the application of safety measures developed, farm-fire losses have been reduced from $120,000,000 a year to around $80,000,000 according to a recent estimate of the National Fire Protection Association. Another indication of valuable results from this work are reductions in insurance rates of 93 percent on grain elevators, 74 percent on starch factories, and 90 percent on grain threshing machines.

The principles and methods of the dusting of cotton from airplanes to reduce boll weevil damage were discovered and patented in the course of the Department's pioneer work in cotton production. Cotton ginning itself has been placed upon a much more scientific basis through work of the United States Cotton Ginning Laboratory at Stoneville, Miss.

The development of the variable-depth cotton planter which makes possible good stand no matter if the weather is dry, wet, cold or hot, took place in 1935. Use of the machine designed by Department engineers eliminates most of the poor stands of cotton and thus saves both labor and seed. Several manufacturers have employed the principle in making planting machines which are now in use on many cotton farms.

New principles have been developed for the better handling of high-moisture silage, grass silage having become a common feed in recent years, and requirements for silos to hold it have been discovered. Better farm practices and improved machinery have been devised to aid in control of the European corn borer.

At Ames, Iowa, cooperative investigations have been carried out on the equipment and methods used in corn growing. These have shown ways to economize in the use of labor, an important matter in wartime. For example, they have shown how to cut down greatly on the labor of seedbed preparation, cultivation, and harvesting. In mechanical harvesting, they have cut the time of changing wagons on the picker, for example, from 12.7 percent of the operating time down to 2 percent.

Department engineers have worked out the requirements of small-grain combines. These were outlined by W. M. Hurst in an article in Agricultural Engineering, a publication of the American Society of Agricultural Engineers, in June 1935. Many of the small combines now in use all over the country were built according to the eleven principles laid down in Hurst's article.

Cooperative work on the development of machinery for use in the growing and harvesting of flax has been carried on for some years in Oregon. This has resulted in improvements in various machines—pullers, de-seeders, cleaners, tow shakers, and so on. An experimental cleaner devised through research and used in one cooperative mill in Oregon in 1942 made unsalable tow salable and brought the group of farmers more

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than $31,000 extra income.

Studies of beet-production machinery have likewise resulted in many improvements, especially in blocking, thinning, and harvesting, also in planting machines. A method has been devised for cracking sugar-beet seed balls into single-germ segments so as to get a higher percentage of single plants. Increased efficiency and much reduction in stoop labor has resulted from this research.

While agricultural engineering was in a separate bureau important work was done on the flow of water in irrigation and drainage ditches. These were important fundamental studies. D. L. Yarnell, one of the engineers in the old bureau, did a piece of work published in 1935, under the title, Rainfall Intensity Frequency Data. It was of great value throughout this country to irrigation and drainage engineers and to those doing work on soil erosion and on city water supplies. The work of the irrigation engineers has achieved national recognition, while the water-measuring flume developed by R. L. Parshall and the results of the work of F. S. Scobey on the flow of water are in worldwide use.

In recent years Department engineers have done notable work on improvements in plow designs which have resulted in lighter draft and better trash coverage. Much of this work was done at the Tillage Machinery Laboratory at Auburn, Ala.

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accepted by all fertilizer-machinery companies, and most of the machinery for the crops so far studied is now designed to place the fertilizer exactly in accordance with recommendations based on experiments.

Improvements have been made in dusting and spraying machinery as a result of research on the requirements of various crops and on the make-up of the various sprays and dusts. Now a much better job of disease and insect control can be done while at the same time less material is used.

The Cotton Ginning Laboratory

The United States Cotton Ginning Laboratory was established at Stoneville, Miss., in 1930, under an act of Congress authorizing investigations in this field. It comes under the Bureau of Plant Industry, Soils, and Agricultural Engineering. Losses resulting from poor ginning were estimated at more than $15,000,000 annually. Poor ginning leads to low-quality cotton from the standpoint of spinners and loss to cotton growers. The work at the Laboratory covers all phases of picking, handling, ginning, cleaning, and packaging cotton. Improved and more economical ginning methods are the objective. The Laboratory is equipped with virtually all standard makes and types of ginning machinery.

The use of good mechanical driers for the conditioning and proper drying of damp, green or wet seed cotton, as recommended by the Laboratory, has been found to increase the value of ginned lint from 70 cents per bale on short cottons to $2.50 on longer staples. It also enhances

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the germination and milling quality of the seed. Mechanical driers developed by the Laboratory are now used in more than 10 percent of all gins. Public-service patents have been issued under which the advantages of such mechanical drying of seed cotton before ginning are made available to the public gratis.

The use of these driers increases the gin turn-out of cotton, reduces breakage of fiber, and thus increases the average staple length. Dry cotton is also more easily cleaned, hence spinners get a better product. The larger gins are equipped with such driers now, hence the proportion of seed cotton so dried is much greater than the number of gins using driers would indicate.

Many tests have also been made of gin-saw speeds and seed rolls. Increasing the saw speed from 400 to 600 revolutions per minute and ginning with loose seed rolls has been found to increase gin capacity almost 20 percent with both the longer and the shorter staple cotton. In terms of value this means an additional out-turn amounting to more than $2.50 a bale for long-staple and $1.50 a bale on short-staple cottons. The benefits from increasing the saw speed in ginning with loose instead of tight seed rolls have ranged up to $4 a bale on long-staple cotton.

The Laboratory's work has attracted wide attention. Large groups of ginners and growers from a number of important cotton-growing States visit it regularly, spending several days there. It serves as a training school for State extension specialists who come for a week nearly every spring. General information is disseminated over the entire Cotton Belt

by means of radio, published bulletins, leaflets, and circulars dealing with specific phases of the equipment maintenance, and operation of gins. Selected samples of cotton ginned at the Laboratory are used in actual spinning tests by cooperative Federal-State testing laboratories.

Other subjects of study are gin-saw design and maintenance; the use, repair, and replacement of brushes; packaging with various bale coverings and using different bale densities; the handling of seed to maintain purity; the reduction of power waste; and such special problems of an individual or regional nature as may arise. The Laboratory's recommendations in all fields are widely used by ginners, farmer-ginners and manufacturers of ginning machinery.

Tillage Machinery Laboratory

The Tillage Machinery Laboratory at Auburn, Ala. was completed in 1935. The Laboratory forms an administrative part of the Bureau of Plant Industry, Soils, and Agricultural Engineering. It is the only one of its kind in the world. Its purpose is to provide facilities for the comprehensive study of tillage tools under controlled conditions in a variety of representative soils. Here it is possible to test tillage equipment under various soil conditions within a very short period without encountering any of the objectionable variables usually met in field testing. Arrangements are made for designers of tillage tools to utilize the Laboratory's facilities.

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be salvaged for post-war farm work. The variable-depth cotton planter, now in use on many plantations of the South, was invented here. Here also was developed information on the draft of plows, and on the effects of pneumatic tires on farm implements, especially as related to traction, draft, and soil packing.

The reactions of various machines, including plows, to soils of different types have been investigated. Basic information on the improvement of tillage methods has been developed. It has been shown that on certain soils rough preparation, which requires less time and labor, nevertheless produces a better yield of cotton than the usual method requiring more operations and fine tilth. In some cases the quality of the cotton appeared to have been improved by use of this method. Department work on plows carried on elsewhere resulted in the invention of a self-alining disk jointer which covers trash better and reduces the draft of the plow from 10 to 15 percent.

The Army's jeeps indicated, in the tests, that after the war they would prove highly useful as supplemental power for road use, light plowing, and other field work, except the cultivation of row crops. In reality the jeep is quarter-ton reconnaissance car.

Sugar Beet Mechanization

It is now practicable both to thin and to harvest sugar beets mechanically, the former with one-tenth to one-half the usual number of workers, the latter with one-sixth the present labor requirement.

This has resulted from cooperative work of Department engineers with the Colorado and California Agricultural Experiment Station workers.

Mechanical thinning experiments were started about ten years ago at a time, however, when labor was plentiful. At present, with labor scarce the methods developed are of prime importance. The same is true of mechanical harvesting during the wartime labor scarcity. A commercial trial of the non-stoop thinning method resulted in savings of $4.50 per acre on the entire sugar beet crop. Mechanical harvesting also leaves the byproduct, the tops, in better condition for cattle feed than does hand labor. The machine misses fewer beets, too.

Fiber Flax Machinery

War has given impetus to improvements in the fiber flax industry in this country. In 1941, Oregon, the principal fiber flax State, grew 20,000 acres compared with an average of only 2,000 acres preceding 1935. Before Pearl Harbor, engineers and crop men of the Department and the Oregon Agricultural Experiment Station had begun work to improve machines, growing methods and processing and the industry had begun to take on new life. The war in Europe had cut off supplies of fiber and linen products from the usual sources and this had stimulated expansion here. Now improvements through research are adding to the stimulus, resulting already in the tenfold increase acreage.

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Mechanical blocking experiments were started about ten years ago as a time, however, when labor was plentiful. At present, with labor scarce the methods developed are of prime importance. The same is true of mechanical harvesting during the wartime labor scarcity. A commercial trial of the one-stroke blocking method resulted in savings of $4.50 per acre on the entire sugar beet crop. Mechanical harvesting also leaves the by-product, the tops, in better condition for cattle feed than does hand labor. The machine places fewer beets, etc.

Fiber Flax Machinery

War has given impetus to improvements in the fiber flax industry in this country. In 1941, Oregon, the principal fiber flax state, grew 18,000 acres compared with an average of only 2,000 acres preceding 1935. Before Pearl Harbor, engineers and crop men of the Department and the Oregon Agricultural Experiment Station had begun work to improve machines, growing methods and processing and the industry had begun to take on new life. The war in Europe had cut off supplies of fiber and linen products from the usual sources and this had stimulated expansion here. New improvements through research are adding to the stimulus, resulting already in the tenfold increase acreage.

Before this war broke out, flax-processing machinery in this country came chiefly from Belgium, but now domestic manufacture has begun and special equipment may be obtained on order. Research has made improvements in machines for pulling or harvesting, in scutching, in tow shaking, and in the processes necessary to separate the fibers. The industry does not yet have mechanical equipment comparable to that in use on major crops such as grain combines and corn harvesting machinery, but the engineers expect rapid progress now that a start has been made.

New Things In Potato Storage

Recent improvements in potato-storage houses resulting from research in the Bureau of Agricultural Chemistry and Engineering make it possible to store potatoes, at least in the North where tests have been made, with less rotting of the tubers and of the timbers in the storage house. Temperature and moisture control are mainly by conduction of heat and the condensation of moisture on moisture-proof surfaces. The application of the results of this piece of research should save farmers thousands of dollars a year particularly in the North where losses from rotting have been great.

When a storage has waterproof walls and potatoes are kept from direct contact with the outside wall the moisture condenses on the cool, smooth surface and runs down to a gutter on the floor and out. The method requires less artificial heat and it is not necessary to watch the stored potatoes so closely as is the case when more dependence is placed on ventilation. Also there is much less shrinkage of potatoes by this method

which provides better control of moisture than the old ventilation method. Proper design and construction are the keynotes, and plans are being worked out for storages of different sizes to meet conditions in various parts of the North.

Right Place for Fertilizer

Farm machinery engineers have found that for many of the common crops it is best to place the fertilizer in bands about 2 inches each side of the row and slightly below the level of the seed. However, seedlings of some crops are so sensitive to strong fertilizer solution in the soil that the placement must be farther away. Surprising increases in yield have been obtained with many crops with no increase in the amount of fertilizer but simply through proper placement of the usual amount. The gains over common practice are frequently from 25 percent to 40 percent. The new practices are already in wide use on farms.

Recent Investigations

Recent engineering studies have yielded useful information regarding farm buildings and heating equipment, improvements in machinery for the farm and processing plants, and profitable uses for electricity on the farm. Some specific examples follow:

Temperature differences between floor and breathing height in houses cannot be wholly overcome through changes in heating equipment, but can be done away with largely through the use of storm sash, weather stripping, and insulation, thereby increasing comfort and saving fuel.

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Recent Investigations

Recent engineering studies have yielded useful information regarding farm buildings and heating equipment, improvements in machinery for the farm and processing plants, and profitable uses for electricity on the farm. Some specific examples follow:

Temperature differences between floor and breathing points in houses cannot be wholly overcome through changes in heating equipment, but can be done away with largely through the use of storm sash, weather stripping, and insulation, thereby increasing comfort and saving fuel.

Studies of low-cost houses in the South showed ordinary window shades reduce summer house temperature 3° to 4° F. Slatted blinds on the outside seem even more effective, but the conventional high ceilings of this region did not prove to be a comfort factor. As insulation, cottonseed hulls 3-5/8 inches thick over the ceiling reduced fuel consumption in winter 16 to 25 percent.

Economical wattage and arrangement of electric lights were worked out for dairy barns--ordinary 60-watt bulbs back of every fourth cow, those of one row staggered with the opposite row.

A so-called "shell-cooled" potato storage was developed in which there is less rotting of potatoes and less deterioration of buildings, with less care needed to maintain the right temperature and humidity.

Wind-pressure ventilation was found to have advantage in the storing of ear-corn, wheat, and grain sorghum.

Discoveries regarding variations in capacity of dusting nozzles and differences in mixing and spreading properties of powdered insecticides, fungicides, and diluents promise more efficient and economical control of crop pests. A new self-propelled machine with high ground clearance was devised for spraying sweet corn.

Studies at the Cotton Ginning Laboratory have shown that modern gins can be altered at small expense to press cotton bales to a density of 20 pounds to 25 pounds to the cubic foot instead of the usual density of 13 pounds. This means a saving of 35 percent in shipping space and comparable savings in bale covers and ties.

Studies of low-cost houses in the South showed that wide window shades reduce summer house temperature 5° to 10° F. Outside blinds on the outside were even more effective, but the conventional high ceilings of this region did not prove to be a comfort factor. In insulation, cottonseed hulls 3-5/8 inches thick over the ceiling reduced fuel consumption in winter 16 to 25 percent.

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Studies at the Cotton Ginning Laboratory have shown that modern gins can be altered at small expense to press cotton bales to a density of 30 pounds to 40 pounds to the cubic foot instead of the usual density of 12 pounds. This means a saving of 75 percent in shipping space and comparable savings in bale covers and ties.

Other new mechanical developments of interest to farmers include a new single-seed sugar-beet planter which requires less seed and cuts thinning cost, a beet topper, better plow points, the use of water to keep the soil from sticking to plows, the discovery that disks beveled on the inside of the cutting edge pull much easier than those beveled on the outside, improved husking rolls for picker-huskers that reduced shelling loss of corn from 5.65 bushels to 1.95 bushels an acre, equipment and methods for growing sweetpotatoes that promise lower costs and improvements in machines for harvesting and putting up grass for silage.

Developments from cooperative studies of profitable farm uses for electricity include economical cooling of eggs, new facts on chick brooding and brooders, heating of farrowing houses that reduce losses of pigs and increase rate of growth, and warming of drinking water for livestock.

SECTION XII

RESEARCH IN AGENCIES THAT HAVE BEEN TRANSFERRED FROM THE DEPARTMENT

Valuable research was carried on by certain administrative units that were originally created within the framework of the Department of Agriculture in response to definite needs, but which were later transferred to other agencies. Outstanding scientific work performed by the personnel of these agencies while they were part of the Department of Agriculture belonged to this Department and merits brief exposition.

This section, therefore, deals with such scientific contributions by the staffs of the following agencies, treated in the order in which they became offices or bureaus of the Department of Agriculture: The Weather Bureau, The Bureau of Public Roads, The Bureau of Biological Survey, and The Food and Drug Administration.

Weather Bureau

Beginnings

Organized weather service in the United States was inaugurated by the approval on February 9, 1870 (16 Stat. L., 369), of a Joint Resolution of Congress. The service was actually started November 1, 1870, as a part of the Signal Service of the Army, largely because of the desire to provide

a peacetime usefulness for that organization, whose personnel at Army posts throughout the country, especially in the middle and western States, provided a ready-made network of stations, where observations of the weather had already been made to a limited extent.

The plan of organization was largely due to Cleveland Abbe, who directed the technical and scientific work of the new service, while the observational and administrative work was placed in the hands of the officers and enlisted men of the Signal Service. The name was changed to Signal Corps in 1880. A group of civilian scientists assisted Professor Abbe with the technical functions, supplemented as time went on by commissioned officers of the Signal Service assigned to meteorological work, who became proficient largely through instruction given by a number of leading meteorologists outside the Service.

Training of the enlisted men assigned to duty as weather observers was accomplished at Fort Myer, Va., originally named Fort Whipple. The Fort Myer school continued until 1886. Many of the men thus trained continued in the Weather Bureau when it became an agency of the Department of Agriculture July 1, 1891, pursuant to the passage of an Act of Congress, on October 1, 1890, transferring the weather service from the Signal Corps. Mark Harrington was then Chief. The Weather Bureau was transferred to the Department of Commerce under Reorganization Plan No. IV, effective June 30, 1940.

During the Signal Corps period the technical and research work of the weather service was developed by such civilian scientists as Cleveland Abbe, C. F. Marvin, Henry E. Williams, A. J. Henry, H. C. Frankenfield,

O. L. Fassig, H. H. Kimball, and others who continued their work for a long time after the Weather Bureau became an agency of the Department of Agriculture.

During its early years in the Department a bulletin on magnetic observations on soil and climate by E. W. Hilgard, one on the processes of soil formation, and others on the physical properties of soils by Milton Whitney were published. Both authors later became well-known Department soil scientists.

Forecast And Warning Services

Forecasts of weather and warnings of severe storms, floods, cold waves, etc., have been the principal concern of the organized weather service since its beginning in 1870. The securing of adequate synoptic surface observations as a basis for the preparation of weather maps from which forecasts are made thus becomes the primary objective, accompanied by the prompt collection of observations at forecast centers by means of an adequate communications system.

Cleveland Abbe and his civilian colleagues were primarily responsible for the inauguration of the forecast service. The accuracy of the observations necessarily depends upon the accuracy of the instruments employed, so that forecasting results from the combined effort of several related service units, and the work of many.

Improved forecasting has resulted from better and more frequent observations from an increasing number of stations, and in 1896 surface observations began to be supplemented in a small way by much-needed

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Improved forecasting has resulted from better and more frequent observations from an increasing number of stations, and in 1898 surface observations began to be supplemented in a small way by upper-air

observations from the upper air by means of kites carrying meteorographs. This result was accomplished chiefly through the efforts of C. F. Marvin and others active in providing proper instruments and facilities.

About 1918 airplane flights to carry meteorographs began to be used and had entirely replaced kites by 1931. Their use reached a peak about 1937 when the radiosonde became practical. Pilot-balloon observations taken with theodolites, giving wind direction and velocities aloft have been of substantial benefit to forecasters, beginning about 1918 and steadily increasing, so that by 1940, 133 stations reported observations made four times daily.

The outstanding development in upper-air observations came with the advent of the radiosonde, first in experimental flights in 1936 and 1937, followed by the establishment of six regularly reporting stations in July 1938, steadily developing to a total of 35 stations by 1940 making one observation daily. The radiosonde has the marked advantage of providing quickly a record of temperature, relative humidity, and atmospheric pressure aloft by means of a radio receiver and other ground equipment which intercept and record the radiosonde signals. Development of this equipment was accomplished cooperatively by the Weather Bureau, the Bureau of Standards, other scientific agencies, and manufacturers. Radiosondes have superseded kites, and to a large extent airplanes, as mediums for upper-air soundings.

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be worth many millions of dollars per annum. For example, warnings of a single destructive hurricane kept shipping worth $30,000,000 safely in port. Flood warnings have been particularly valuable as separately mentioned later.

With the coming of the airplane a new field was opened to the forecaster, a modest start being made about 1926 when forecasts were made available to the Post Office Department, then flying the mail. Commercial aviation expanded and by 1930 route and terminal forecasts for the network of airways began, constituting a marked achievement in the use of meteorological service.

Upper-air observations received an impetus with the development and application of the polar-front theory, and its accompanying use of air-mass analysis. Surface observations are alone inadequate for the application of air-mass analysis to forecasting; hence frequent upper-air observations from a sufficiently close network of stations is a necessity. By 1940 such a network was in process of realization, through the use of radiosondes and pilot balloons.

Weather Bureau personnel have been prominent in advancing the cold-front theory and the use of air-mass analysis, notably C. G. Rossby, H. Wexler, and H. R. Byers from the scientific side, and others, mostly active forecasters assigned to the task of making practical the application of these useful concepts. In the latter group are names familiar to the Weather Bureau and to a considerable portion of the public served, such as C. L. Mitchell, F. W. Reichelderfer, R. H. Weightman, E. H. Bowie, and other district forecasters.

In the earlier days, before the use of the polar-front theory, well-remembered forecasters contributing to both the scientific and practical development of forecasting were Edward A. Beals, F. H. Brandenburg, I. M. Cline, H. J. Cox, H. C. Frankenfield, E. B. Garriott, A. J. Henry, C. Hallenbeck, James A. Kimball, Alexander G. McAdie, James H. Scarr, J. W. Smith, and numerous others among the local forecasters. All helped to make the service fully effective and beneficial to the public.

Forecasts and warnings of damaging floods, which service has been required of the Weather Bureau virtually since its inception, are in a class apart from the general weather forecast service, although related thereto. Flood forecasts require a special technique whereby daily or special reports of precipitation over a given watershed, together with gage readings of the river and its tributaries, are used with forecasts of precipitation, estimated run-off and other factors, to provide accurate estimates of prospective flood stages threatening life and property.

The development of this technique of flood forecasting by Weather Bureau personnel has been a most creditable achievement. The work of H. C. Frankenfield, long the Chief of the River and Flood Division, stands out, for early in the century he set the example to be followed by the officials at River District centers, entrusted with the details of such forecasting and the necessary close contacts with the public. Names of some of the officials who should be mentioned are

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William E. Barron, William T. Blythe, William E. Brotzman, I. M. Cline, William C. Devereaux, and Montrose W. Hayes. Recent progress in perfecting forecast procedure has been accomplished by Merrill Bernard, Hydrologic Director in charge of River and Flood work, and his associates.

As evidence of the valuation placed upon warnings of floods issued by the Weather Bureau, the following letter is an example; hardly a year goes by that a major flood does not require this protective service:

THE SECRETARY OF COMMERCE

Washington, D. C., July 5, 1927

Hon. William M. Jardine,

Secretary of Agriculture,

Washington, D. C.

Dear Mr. Secretary:

There has been a service performed during the flood in Louisiana * * which should be made a matter of illuminated record in your archives.

Dr. Cline made a series of day to day estimates of the flood and its progress for over 2 months of its movement from Cairo to the Gulf. They were based upon a wealth of technical understanding and experience that was almost uncanny. We came to rely upon them and to build the whole organization and direction of our rescue operation upon them. With the advance information which he was able to give us on the action of the flood we were able to interpret it into a saving of thousands of human lives. Moreover the issue of this material to the public by Dr. Cline in such terms as to give confidence and understanding resulted in the saving of great life and property without any action on our part.

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His office was in service day and night with no demand that we could make that was not more than answered. Without the accurate information which he supplied I believe that New Orleans might have gone under water.

It has been much more than the mere routine interpretation of technical data. It required judgment and discretion, which amounted to genius. He has been an honor to the Weather Bureau and the whole Department.

Faithfully yours,

(Signed) Herbert Hoover

Special service has been featured for many years to provide forecasts which enable growers to protect their valuable fruit and orchards from damage by frost and freezing temperatures. This service has been centered and intensified in the citrus fruit areas of California, Florida, and the valley of the Rio Grande in Texas. It had its beginnings in California about 1913 under the direction of Floyd D. Young.

Briefly stated, when a severe frost is expected the orchards are heated to raise the temperature of the air and the fruit to an extent sufficient, if possible, to prevent or minimize damage to the fruit. Heating of orchards is accomplished almost universally by means of oil-burning equipment properly placed between the trees. When a general forecast of frost is issued for an area devoted largely to fruit production, the officials in charge of the special Weather Bureau service adapt it to the detailed needs of the fruit growers, specifying the degree of cold expected, time and duration of damaging temperature, wind, and weather during the critical period. Thus the grower is

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given a picture of the weather and temperature conditions to be experienced at least from late afternoon until well into the following morning. He is thus enabled to measure the heating to the needs presented, without waste of time, fuel, or labor. By this procedure many valuable crops have been saved or undue damage has been prevented.

Young who started the service, continued active in its direction to 1940, expanding its scope and helpfulness. Others have been trained and assigned to supervising duties in other sections of the country. Mr. Young is the author of a Farmers' Bulletin 1588, Frost and the Prevention of Frost Damage, wherein the subject is treated both scientifically and practically. Other fruits are protected from frost damage by suitable means, not only deciduous tree fruits but small fruits such as strawberries and cranberries.

Forecasting is done in its relation to the protection of valuable forests from fires which are started by lightning or accidentally when weather and other conditions are favorable. Protection is made possible through an accurate knowledge of current weather, humidity, temperature, wind direction and velocity, visibility, etc., coupled with forecasts of changes which affect the degree of hazard from fire.

Forecasts of wind, precipitation and lightning storms affect the starting, progress, and control of forest fires. The Forest Service and the Weather Bureau have long collaborated in this work of protecting and conserving the forests.

Climatological and Crop-Weather Services

Climatology is based upon regular, daily observation of weather, temperature, wind, precipitation, and other elements obtained from a widespread network of stations. An effective service did not begin in the United States until well after the establishment of the Weather Service in 1870. Observations at the beginning of the Service, while partly intended for climatological use, were mainly directed toward the preparation of synoptic maps for forecasting.

But, in 1887, under the administration of A. W. Greely, real growth began with the establishment of stations to provide observations directly for climatological use--stations mainly of the cooperative type. This network of cooperative stations was further augmented in accordance with the Act of Congress establishing the Weather Bureau as an agency of the Department of Agriculture. These cooperative stations continue to be the principal source of information for a comprehensive climatology. Growth has been steady, and in recent years upper-air, marine, and airway observations have been added to the accumulated data, thus extending the climatology of the United States to the contiguous bodies of water, and to the atmosphere above the surface.

Outstanding work in this field naturally centers in the preparation and publication of works on climatology, more especially for the United States and its possessions. The first comprehensive climatology prepared by the Weather Bureau was published in 1903 as Bulletin Q, under the supervision of A. J. Henry. Revisions have been

Climatological and Crop-Weather Services

Climatology is based upon regular, daily observation of weather—temperature, wind, precipitation, and other elements—obtained from a widespread network of stations. An effective service did not begin in the United States until well after the establishment of the Weather Service in 1870. Observations at the beginning of the service, while partly intended for climatological use, were mainly directed toward the preparation of synoptic maps for forecasting.

But, in 1891, under the administration of M. W. Harrington, real growth began with the establishment of stations to provide observations directly for climatological use—stations mainly of the cooperative type. This network of cooperative stations was further expanded in accordance with the Act of Congress establishing the Weather Bureau as an agency of the Department of Agriculture. These cooperative stations continue to be the principal source of information for a comprehensive climatology. Growth has been steady, and in recent years upper-air, marine, and airway observations have been added to the accumulated data, thus extending the climatology of the United States to the contiguous bodies of water, and to the atmosphere above the surface.

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necessary at intervals of ten years or so, and the form of publication has been altered, separates being now issued, sometimes for States but usually for a subdivision of a State. These separates are titled Climatological Summary of the United States. Another useful publication is issued monthly and annually, entitled Climatological Data.

These developments and growth have resulted from the combined effort of the many—the observers both in and out of the Government service, and the officials whose task it was to collect and analyze the data and assemble it in a readily understandable statistical form. Among the many Weather Bureau men who might be mentioned because of their work in climatology, usually section directors are: W. H. Alexander, J. Cecil Alter, James W. Berry, Frank H. Bigelow, Thomas A. Blair, George S. Bliss, I. W. Cline, Preston C. Day, O. L. Fassig, S. D. Flora, Edwin F. Gittings, A. J. Henry, J. P. Kincer, W. A. Mattice, George W. Mindling, Clinton E. Norquest, Charles D. Reed, Wesley W. Reed, J. Warren Smith, A. H. Thiessen, Charles F. Von Hermann, and John R. Weeks.

A special service of the Weather Bureau of long standing is the issue of bulletins of current weather and temperature conditions as they affect agriculture pursuits, and the farm operations incident to soil preparations, seeding, growth, cultivation, and harvesting. The principal publication of this character is the Weekly Weather and Crop Bulletin issued by the Central Office of the Weather Bureau at Washington, D. C.

In it is found a summary of weather conditions for the past week for the entire United States, accompanied by statistics giving the precipitation and mean temperature for the week and their departure from the normal.

This material is accompanied by a general summary of crop conditions and work as affected by the current weather with individual reports from the several States. Two Weather Bureau officials have been responsible for its success over a long period—J. B. Kincer and W. A. Mattice, both in the Climate and Crop Weather Division.

Meteorological Instrument Design and Research

The design and perfecting of the meteorological instruments and apparatus used by the bureau must necessarily go hand in hand with the service developments and observational requirements. C. F. Marvin did outstanding work in that field, especially before his appointment as chief of bureau in 1914. He entered the service in 1884, and during most of the time to 1914 was Chief of the Instrument Division.

The design or radical improvement of the following-named instruments is among his achievements, accompanied in several instances by research as for example in solar radiation: Photographic sunshine recorder (1891), mercurial sunshine recorder (1893), nephoscope (1896)—first Weather Bureau design, anemometer (improvement), weighing rain and snow gage (approximately 1900), tipping-bucket rain gage (1894), automatic river gage (1904), hair hygrometer (1908), solar radiation equipment, especially the pyrheliometer (1910), mercurial barograph (1904), kite meteorograph, kite reel and accessories (1897), shielded rain and snow gage (1910), float rain and snow gage (1913), sounding balloon meteorograph (1919), kiosk (1907 - 1908), seismographs.

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During most of the period from 1914, B. C. Kadel and S. P. Fergusson were mainly responsible for improved or new instruments and apparatus. The former, Chief of the Instrument Division, is credited in particular with the following:

The 1/60th-mile anemometer, required mainly for use at airway observation stations; wind-velocity and direction indicator for the same service; micrometer evaporation hook gage, similar to C. F. Marvin's but more simple; evaporation stillwell.

The name of S. P. Fergusson (1916-1933) is associated with the following: The 3-cup anemometer (new design, 1922), weighing rain and snow gage (1922), wind vane, all-metal (1923), anemoscope (redesign after Draper, 1917), wind-vane electrical contacts (redesign of old-style contacts), balloon and airplane meteorographs (1918-1919).

Personnel other than those of the Instrument Division have contributed much to the betterment of instrumentation, mainly because of their observation of the exacting performance of equipment at field stations. J. Cecil Alter was active in the research and development of effective wind shields for precipitation gages, carried out in experimental installations in Utah where he long served as section director in the Climatological Service.

O. L. Fassig was responsible for the first Weather Bureau ombroscope for the automatic determination of the beginning and ending of rainfall. Fergusson rebuilt the instrument in 1920. Snow-sampling apparatus was developed by both Marvin and Kadel, the latter having field experience in the stream-flow experiments at Wagon Wheel Gap, Colo. This equipment

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The name of S. P. Ferguson (1925-1939) is associated with the following: The 3-cup anemometer (own design, 1928), weighing rain and snow gage (1926), wind vane, all-metal (1929), meteorograph (redesign after Draper, 1937); wire-type electrical contacts (redesign of old-style contacts), balloon and airplane meteorographs (1928-1939).

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is useful in connection with surveys of snow depth and density by means of which estimates are made of the run-off resulting from the snow melt in the spring, which information is valuable in several western States which depend upon such water for irrigation and water power.

Research and Investigations in Meteorology

Research in meteorology by Weather Bureau scientists has always been carried on, although to a limited extent, for the Weather Bureau is eminently a service organization. Its scientific achievements have been directed almost entirely toward the development of such services. However, there have been notable exceptions whereby the science of meteorology has been substantially benefited through applied physics and mathematics with analyses of meteorological observations. A better understanding of the atmospheric circulation and a logical explanation of the evolution of storms and other allied phenomena have been the objectives. Without such fundamental knowledge applied meteorology could not function.

Cleveland Abbe was an early contributor to this scientific research. At the opening of the century a peculiarly valuable study was published as Volume II, Report of the Chief of the Weather Bureau, 1900-01, entitled Report of the Barometry of the United States, Canada, and the West Indies. This study was made by Frank H. Bigelow, and it continues to be a standard work of reference on the subject.

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other writings constitute a rich fund of information. He is credited with the first explanation of the existence and the characteristics of the stratosphere (1909).

C. F. Brooks, while with the Bureau (1918-21), and since, as an outstanding figure in the field of meteorological education, has added much both to theory and practice. He assisted in preparing the climatic section of the Atlas of American Agriculture (1918-1922), for which J. B. Kincer, now Chief of the Climate and Crop Weather Division was primarily responsible.

In recent years new additions to the Bureau's scientific staff have been active in advancing the explanation and usage of the polar-front theory and air-mass analysis, notably F. W. Reichelderfer, the present Chief of Bureau, C. J. Rossby, H. R. Byers, H. Wexler, and others.

Of equal or greater scientific importance than theoretical research are investigations which provide a first-hand, direct knowledge of atmospheric phenomena. Such investigations have long featured Weather Bureau activity. Outstanding are the following:

Upper-air soundings by means of kites, sounding and pilot balloons, airplanes and radiosondes, which provide a continually increasing knowledge of the meteorological elements above the earth's surface. Among those closely connected with this development, the following may be named:

William R. Blair, C. F. Brooks, S. P. Fergusson, Dr. W. R. Gregg, (Chief of Bureau, January 1934 - September 1938), L. P. Harrison, A. J. Henry, W. J. Humphreys, V. E. Jakl, C. F. Marvin, L. T. Samuels, and B. J. Sherry. Space precludes the naming of the many men at field

stations who faithfully carried out their share of such investigations. The data are invaluable for study, analysis, and use in forecasting, climatology, etc.

Other investigations which merit special mention are the following:

The experimental measurement of dew-point temperatures employing modified forms of both Regnault's and Alluard's dew-point apparatus made by C. F. Marvin, assisted by H. A. Hazen. These fundamental measurements were used in the preparation of the Weather Bureau Psychrometric Tables, continually employed for meteorological observations to obtain relative humidity, vapor pressure, etc.

Solar-radiation measurements by means of pyrheliometers began in 1901 and have continued to date. The objective is to measure or record the intensity of solar radiation at the earth's surface expressed in gram-calories per square centimeter per minute. This work was organized and developed by C. F. Marvin, H. H. Kimball, and Irving F. Hand. Several widely separated stations carry on these investigations.

Streamflow experiments utilizing weirs, and other devices, were made at Wagon Wheel Gap, Colo., under the direction of B. C. Kadel, assisted by Harris A. Jones and others, starting in 1910 and ending in 1926. The principal objective was to determine the effect of a forest cover on streamflow.

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1939, pursuant to Reorganization Plan No. I, the Bureau of Public Roads was transferred to the Federal Works Agency where it became the Public Roads Administration. The following account briefly covers research accomplishments of scientists in this field between the two dates mentioned.

Following the Revolutionary War there was marked interest in highway improvement, however; several turnpikes were built, and, in 1806, the Federal Government embarked on the construction of a National Pike from Baltimore westward across the Appalachian Mountains to Ohio, Indiana, and Illinois. Then the United States passed through a "dark age of road building," a considerable period when there was little interest in the subject.

About 1830 the railroad period dawned and work on the National Pike ceased. In the eighties farmers began to complain about mud roads, but they were ill-organized and little attention was paid to them. In 1885 bicycles of modern type began to appear on highways and cyclists clubbed with farmers in urging better roads. In 1888, Commissioner of Agriculture Colman stressed in his annual report the urgent necessity for a well-regulated system of public highways.

At that time the Dean of the Engineering Department of Vanderbilt University, at Nashville, Tenn., had undertaken an investigation of highway systems, and had tendered the results to the Department which lacked funds to take over the study. A National League for Good Roads was organized and held its first meeting at the Columbian Exposition in Chicago in October 1892. At that time almost all the rural roads were

of unimproved dirt, care being in the hands of county or local officials and very superficially applied, and highway travel between major cities was all but unknown. Yet a hundred road-improvement associations and boards of trade were represented at the Chicago meeting. Plans were discussed for local, State, and national legislation, as well as for the creation of a national commission of road inquiry. At this time the League of American Wheelmen became increasingly active in demanding that something be done about poor roads; it began to publish a monthly called Good Roads.

In response to this growing sentiment there was inserted in the Agricultural Appropriation Act for the fiscal year beginning July 1, 1893, a paragraph appropriating $10,000 for road-management inquiries, and investigations of road making, with publication of the results. Under this authority the Secretary of Agriculture created an Office of Road Inquiry. Roy Stone, of New York, a civil and mechanical engineer and a veteran General of the Civil War, was appointed Special Agent and Engineer for Road Inquiry on October 3, 1893.

The scope of the work was limited as was the appropriation. For some years it was advisory and cooperative, though specimens of road material were collected, national roads were mapped, surveys were made of State road work, and the small staff attended numerous conventions. Gravel highways and macadam and other stone roads were studied principally. At that time the automobile was not a factor. In the first 9 months of its existence the Office expended $7,848.

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success of State aid to counties in New Jersey. The small staff sought to become expert in an almost unexplored field. Highway engineering was then an unknown profession and there were no State nor county highway departments.

The report of 1893 speaks of a stone road in New Jersey costing $3,500 per mile, of many miles of "good telford road built in Kentucky at $2,000 per mile," of "one track of stone and one of earth" in Georgia costing $1,200 per mile, and of a "single-track stone road" in New York costing $900 per mile. The same report also cited the difficulties encountered by farmers in moving crops to markets.

The report of 1895 advocated State and county aid to road improvement, a plan initiated in New Jersey in 1891. By 1895, benefits were so evident as to cause widespread discussion and other States were considering the plan, a first step toward State control of main highways. In this year the collection of specimens of road material from all parts of the country began.

In 1896 a National Road Parliament was held at Atlanta, Ga., and was attended by delegates from 32 States. The Office of Road Inquiry had constructed a sample road on the Atlanta Exposition Grounds. Demonstrations were made of the effort required to haul loads over different surfaces. By now the Office had turned largely to the practical side of road building and to the testing of road materials and the building of short sections of road as object lessons. Some 35 bulletins and circulars had been prepared.

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Actual road construction and experimentation with materials increased. Stone wanted to construct object-lesson roads in every State to demonstrate how easily heavy loads could be carried over good surfaces. The report for 1897 deals with the completion of an object-lesson road at the Agricultural College and Experiment Station in New Jersey, and lists similar projects under way in New York, Rhode Island, and Pennsylvania.

This object-lesson-road period lasted roughly till 1916. Besides its educational value, and the experience gained was of great use later when large road-construction programs were undertaken. By 1901-02 several expert road engineers were employed and the physical and chemical testing of road-building materials was well under way. Early in his administration Secretary Wilson wrote: "Good roads save time and expense. Steel rails are perhaps the coming material where hard rock is not convenient."

Experiments with Steel Roads

The advantage of good road surfaces most accentuated was ease of traction. It was a stock argument that it cost 25 cents per ton-mile to haul farm products on existing road and that this could be greatly reduced by hauling on smooth surfaces. Over 60 years of experience with steam engines hauling freight over steel rails suggested that steel trackways might be used on the highways. The steel companies were interested in developing a new market and search began for a cooperator able to pay $3,500 for the materials for a mile of steel road.

No one was willing to experiment on this scale but in 1895, 500 feet of track was laid in the outskirts of Cleveland. The description reads: "This road is composed of inverted channel bars placed in such a position that they become a tramway or trackway. A broken stone surface has been prepared for the horses to walk upon, and to enable the teamsters to take their wagons on and off the road at will."

In 1898, 260-foot sections of steel-track road were built at Omaha, Nebr.; Ames, Ia.; and St. Anthony Park, Minn. The report listing these experiments also contains the obituary of steel roads when it says, "Imperfections were naturally found which can be easily remedied if steel again becomes so cheap that the manufacturers can take the matter up and make rails of special shapes . . ."

Changes in Name, Organization, and in Administration

The Office of Road Inquiry continued under this name until the issuance of the annual report for 1898. This and later reports bear the designation "Office of Public Road Inquiries." The report carried no explanation of the change, thus suggesting that it was an action taken within the Department of Agriculture. In 1905 the agency became the Office of Public Roads and in 1918 the Bureau of Public Roads.

General Roy Stone directed the organization until June 1898 when he was appointed to the staff of General Nelson A. Miles for service in the Spanish American War. He returned to the Department of Agriculture in January 1899, but only for a few months. Martin Dodge of Cleveland, served as director during part of his absence and was again appointed

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on his final resignation. M. O. Eldridge, later Assistant Traffic Director of the District of Columbia, played an active part in the direction of the work for many years. He was attached to the organization soon after its creation and became Assistant Director.

The Department's road work grew from 7 employees to 165 between 1896 and 1912, and from an appropriation of $8,000 to one of $202,120. At this point the Congress appropriated the sum of $500,000 for the construction of post roads, the States to match each $1 of Federal money with $2 of their own, expenditure and road building to be supervised by the Department experts. The Federal Highway Act of November 9, 1921, providing for the designation of the Federal-aid system of public highways, gave the agency its largest and most important task to date. Road construction in the National forests was also increased.

Results of Promotional Work Became Evident About 1900

In no year before 1901 did the entire expenditures of the organization rise to $10,000 yet seeds had been planted that were beginning to sprout in almost every State east of the Mississippi. Little had been done beyond the Mississippi, partly because of the cost of travel from Washington, D. C. The report for 1900 describes cooperation in construction of object lesson roads in 12 States, 9 of which were east of the Mississippi.

Assistance in building roads was obtained from the railroad companies that wanted to develop the territory they served and from road machinery companies that loaned equipment in expectation of selling it

near the place of use. Financial assistance came from institutions and local groups. The financing of a section of road was undertaken somewhat as a small community now undertakes to raise money for a hospital or a community house except that little aid was available from public treasuries.

Road-building methods that have been brought to a high efficiency in modern practice were sometimes tried in these early years only to be laid aside and forgotten until revived by another generation of of road builders. In 1899 an earth road at Menomonie, Wisconsin, was rounded up, sprinkled with crude oil, and consolidated by traffic. This was a forerunner of the various types of bituminous-treated soil roads.

An object-lesson macadam road was built at Port Huron, Michigan, in July 1900 as a demonstration before a convention of the League of American Wheelmen. A steam traction engine with wide wheels was used as a roller and to pull a road grader and dump wagons. Many years were to elapse before trucks and tractors provided almost unlimited power for highway work.

Railroads of the country contributed to the good-roads movement through their cooperation in operating "good roads trains." From 1901 through 1912 they crisscrossed the country stopping at thousands of towns, villages, and small cities to spread enlightenment on the advantages of good roads.

Enter Motor Traffic

The year 1904 marked the end of a period. Up to that time there had been no significant change in the methods of road construction which had been employed for a century or more. Either of the major types of surfacing--gravel and macadam--gave satisfaction under the traffic normal to the country roads of the time. The other types that had been developed and used in small mileage, such as the shell roads of the tidewater States and the sand-clay roads of the South, were suggested by the availability of the materials rather than by any difference in the demands of the traffic that used them.

Viewed broadly, the few types of surface constructed up to this time may be considered as of one class. In the construction of all the same principles governed; in all a fragmental mass was bound together more or less firmly by a natural cement in the manner made familiar by a century of practice.

The peculiar effect of the automobile on waterbound macadam roads is so well known as to require no description and the way in which the road builders met the challenge by substituting tars and asphalts for the weaker mineral binders is an oft-told tale. First as dust layers, then as protective surface coatings, then as binders introduced into roads of the macadam type by penetration, and finally as hot admixtures according to the bituminous concrete principle, these materials, borrowed from the stock in trade of the city street builder, solved the automobile problem in a way which was apparently entirely satisfactory.

The effect of this development in road-building is shown by comparison of the statistics of 1904 and 1914, the dates which virtually mark the beginning and crest of the wave of bituminois construction. In 1904, according to the records, there were in the entire country only 18 miles of bituminous rural roads, all in Massachusetts and Ohio. By 1914 there were 10,500 miles, a mileage which was nearly three-quarters of the aggregate length of all roads of higher type than macadam.

The Office of Public Roads played its part in this transition to meet the new road requirement. In 1906 a chemical laboratory was established to examine, among other things, the properties of tars, asphalts, and oils. Workers in the laboratories started exploration in a field only slightly explored. Samples of bituminous material were obtained from many sources and subjected to such chemical and physical tests as the workers might devise. At the same time materials from the same sources were being used in a variety of ways on short sections of experimental roads.

Results obtained on the test roads indicated the sources and proportion of materials that could be most successfully used for actual service, and correlation with laboratory data made these tests useful in selecting materials and indicated the test limits to be used in specifications. As knowledge of bituminous materials developed preliminary tests of proposed mixtures were made in the laboratory and only the most promising were selected for more expensive field tests.

In the first years of building bituminous roads there were numerous failures. They were due to using too much or too little of the asphalt or tar, or of the wrong consistency, or material overheated in the manufacturing processes. As troubles developed on any road the laboratory experts were called in to diagnose the cause and to prescribe a cure and preventive measures on future work. The thousand of miles of bituminous roads giving satisfactory service today are the result, not of any single great discovery, but of years of detailed work in the laboratory and on experimental roads.

Sand-Clay Road-Surface Studies

Parallel to the development of bituminous roads another type of surface was being brought into use of great significance to agricultural areas and which was eventually to become a bituminous type in most of its applications. Who was the first man to become interested in those sections of natural dirt road that remained fairly smooth in wet weather and to seek the cause is not known. It was discovered that many such sections were composed mainly of sand with enough clay to bind the sand particles together.

Some local road officials began surfacing roads with material from natural sand-clay deposits but William L. Spoon, road expert of the Office of Public Roads, was apparently the first to realise the full possibilities of this type of construction, to devise test and construction procedures, and to circulate the information among the growing number of would-be road builders. Farmers Bulletin 311, Sand-Clay and

Burnt-Clay Roads was issued in 1907.

This leaflet of 20 pages written in didactic style contained instructions and rule-of-thumb methods for combining sand and clay to make road surfaces. In the light of present knowledge of soils it is an elementary treatise, but it has been the guide in building thousands of miles of low-cost road and it is doubtful whether a more elaborate guide replete with the technical knowledge we now have would have been more valuable. Spoon's methods were fitted to the road equipment and road funds of his time.

Early attempts at treating sand-clay and gravel roads with bituminous material to prevent dust and smooth the surface met with failure. Only those who have ridden over a road where the bituminous mat has partly peeled off can appreciate how bad the failures were. Bituminous research workers soon found what materials to use and how to apply them for successful treatment. Now thousands of motorists ride over surface-treated sand-clay, gravel, and soil roads knowing only that the surface is a bituminous one.

Modern Highway Research

Modern highway research by the Federal Government dates from the passage of the Federal-aid Road Act of July 11, 1916. This act initiated the Federal-State cooperative program of road construction that has played such a substantial part in providing a system of main highways.

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Sand-clay Roads was issued in 1907.

This leaflet of 20 pages written in didactic style contained instructions and rule-of-thumb methods for combining sand and clay to make road surfaces. In the light of present knowledge of soils it is an elementary treatise, but it has been the guide in building thousands of miles of low-cost road and it is doubtful whether a more elaborate guide replete with the technical knowledge we now have would have been more valuable. Spoon's methods were fitted to the road equipment and road funds of his time.

Early attempts at treating sand-clay and gravel roads with bituminous material to prevent dust and smooth the surface met with failure. Only those who have ridden over a road where the bituminous mat has partly peeled off can appreciate how bad the failures were. Bituminous research workers soon found what materials to use and how to apply them for successful treatment. Now thousands of motorists ride over surface-treated sand-clay, gravel, and soil roads knowing only that the surface is a bituminous one.

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Federal-aid funds was authorized for administrative expenses including research, but this was reduced to 2-1/2 percent in 1921. Since May 1918 a monthly magazine Public Roads (now on a quarterly basis for duration of the war) has been issued as a distribution medium for research reports.

Important research began after the first World War, when research facilities at the Arlington Experiment Station were expanded. A large program has been carried on since. The major lines of physical research relate to soils as they affect highways, bituminous materials, non-bituminous materials, pavement surface, and bridge design.

Certain of the research investigations have influenced decisively the course of development of highway transport. At the close of the first World War the highways of the country were in bad shape owing to neglect and heavy traffic during the war and the rapidly increasing number of trucks equipped with solid tires. On one hand a public demand grew up for restricting vehicle loads to the capacity of existing roads. At the same time vehicle manufacturers, sensing the great field for highway transport ahead, adopted the slogan "build the roads to carry the loads."

Either course would have seriously retarded development of our transport system, that in 1942 will move 51 billion ton-miles of freight on its rural sections alone. The organization which had become the Bureau of Public Roads undertook to determine the impact of vehicle wheels on road surfaces and the differences in pavement stresses caused by variations in vehicle loads, tire equipment, and speed.

A first result of the work was demonstration that solid tires are much more damaging to pavements than pneumatic tires. One by one the States applied high tax rates to solid tires or prohibited their use with the result that they rapidly disappeared from the highway.

The series of tests and supplementary investigations relating to structural action of pavements under load has been continued up to the present time. The results have furnished a rational basis for State legislation restricting the weight and speed of vehicles and has guided engineers in the design of pavements.

In carrying out this work especially refined instruments had to be devised and considerable mathematical calculation was required. The studies had to be extended to include the effects of impacts upon culverts of different types constructed of different materials. The study was basic, both to road making and to the commercial success of the automobile industry. Obviously the results facilitated the construction of a road only sufficiently expensive and durable to withstand the impacts it was likely to receive. It also became possible, as a result, to modify load stresses and tire construction so as materially to mitigate wear and tear upon more expensive roads.

Soil Studies

Soil studies were begun at about the same time as the impact studies. The initial purpose was to devise ways of preventing the many road failures attributed to the character of soil beneath the surface. It was known that sandy soils gave good road support and that clay soils did not.

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Beyond this the field was almost unexplored. Thousands of soil samples were taken where failures occurred and from nearby areas where the road remained in good condition.

As there was no standard test procedure for examining such samples, many tests were devised and examined for value in differentiating between good and bad soils. Out of this work has come a standard test procedure and a system of soil classification for the use of the engineer in designing road surfaces to be placed on a given soil and in applying corrective measures to poor soils.

Knowledge of soils that has been developed has a much wider field of application. The soil expert may now take samples of materials from several local deposits, each of which is unsatisfactory for road surfacing, and, guided by test data, combine two or more of them in such way as to make an excellent road base or surface. The materials must have certain qualities which are indicated by the tests. Runways for the Washington National Airport were constructed by this method. Engineers operated a testing laboratory on the field and constantly supervised the mixing of material for the runways.

It is now possible to build excellent low-type roads suitable for light and medium traffic at moderate cost. Soil science has been developed to the point where it is possible to predict the settlement that will take place in 20 or 30 years when a highway is placed across a swamp and what the settlement will be each year during that time.

Fills are now being placed on ordinary ground and surfaced with high-type pavements immediately, whereas in earlier times 1 or 2 years would be allowed for settlement before placing a permanent surface. Unfavorable soils are rejected and, through tests, careful control is kept over water content of the soil to permit a high degree of consolidation. Checks are also made on the consolidation obtained with special rollers. Such knowledge has been used successfully in constructing certain access roads to military establishments and war industries needed for immediate use.

Studies of the Bureau of Public Roads resulted in the development of an altogether new science of soil mechanics. Its scientists showed what various kinds and types of soil would do under varying pressure conditions, what factors contributed to soil stability, and how these reacted under heavy loads. They also furnished the building industry with invaluable facts from which to determine the best manner of laying foundations for large structures. This was an unearned increment of research originally undertaken for another purpose. For it thus became possible for construction engineers to avoid both pavement and foundation failures by giving careful attention to the fundamental principles of soil mechanics established by scientists of the Bureau.

The Bureau of Public Roads has carried on important economic researches. These consisted of traffic and transportation surveys, studies of highway finance, highway planning, and highway maintenance, close cooperation with the American Association of Motor Vehicle Administrators, and investigations of the movement of vehicles at intersections, motor-vehicle taxation statistics, and the determination of the effect on highway traffic of the abandonment of sections of railways.

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Biological Survey

The American Ornithologists' Union memorialized Congress in 1886 for the establishment of a division of economic ornithology, in the Department of Agriculture, to take over the unexpectedly large quantity of data the Union had received in response to questionnaires circulated by committees studying bird migration and the relations of the introduced English sparrow to agriculture. Congress responded with an appropriation of $5,000 to be expended under the direction of the Department's Division of Entomology.

Work began July 1, 1885. The new organization grew steadily and with a doubled appropriation the following year, it became an independent Division of Economic Ornithology and Mammalogy. In 1896 it was designated as the Division of Biological Survey and in 1905 it was made a Bureau. On July 1, 1939, pursuant to Reorganization Plan No. III, the Bureau of Biological Survey was transferred to the Department of the Interior and on July 1, 1940, was merged with the Bureau of Fisheries to form the Fish and Wildlife Service.

The first appropriation bill for the fiscal year 1886 provided "for the promotion of economic ornithology, or the study of the interrelation of birds and agriculture, an investigation of the food, habits, and migration of birds in relation to both insects and plants." C. Hart Merriam, chairman of the Committee on Migration and Geographical Distribution of the American Ornithologists' Union, was appointed to act with the Department's entomologist in these investigations.

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Development

He had been on the Hayden Survey in 1872 and was assistant to the United States Fish Commissioner in 1875; he was recalled from study in Europe to head the work. He remained in charge for 25 years during an epochal period of investigation in which methods of collecting and of museum study of birds and mammals were far improved over those that had earlier prevailed.

It was in these years that Merriam developed his theory that accumulated temperatures during the breeding and growing seasons governed the geographic distribution of plants and animals. This concept was elaborated in numerous publications, one of which, Life Zones and Crop Zones of the United States, as well as various editions of a Zone Map of North America, were distributed by the Department of Agriculture.

In 1891, the then President of the United States, Benjamin Harrison, appointed Merriam as the United States representative on the joint British and American Fur Seal Commission. He was a member of the United States Board on Geographic Names for 20 years and its chairman for 8 years (1917-1925). He resigned from the Biological Survey in 1910 and died March 19, 1942. He was the last of the founders of the National Geographic Society, and Mt. Merriam in California is named for him.

In the second year of existence, the organization's appropriation was doubled and its scope enlarged to include the study of mammals, as well as birds, in relation to agriculture, horticulture, and forestry. Merriam now

wrote reports as the "Ornithologist and Mammalogist." At that time he was aided by only A. K. Fisher, who had been one of the district superintendents of the American Ornithologists' Union migration study, and a single clerk.

In his report dated June 30, 1897, Merriam stated that he had suggested as early as 1889 that there should be a biological survey in the Department. Although Congress had authorized the Division in 1890 to undertake a comprehensive investigation of the geographic distribution of plants and animals, no change in the unit's name was authorized until July 1, 1896, when it became the Division of Biological Survey.

It was then organized in three sections: One on geographic distribution, in charge of Vernon Bailey; one of economic ornithology, under A. K. Fisher; and one of game protection, supervised by T. S. Palmer. Biogeographic investigations were given most emphasis until about 1907 when economic relations became paramount and so remained thereafter. Publication of the results of its extensive field and laboratory work, together with the practical applications of many of the findings, gave the organization a world-wide reputation as a pioneer governmental agency in the biological sciences and the technology of wildlife management.

Early Research

The first work of the newly established unit in 1885--by title the Branch of Economic Ornithology, in the Department's Division of Entomology--was a study of the food habits of birds (and to a lesser extent of mammals) in relation to farm crops and to insects that destroy crops. The English sparrow, ricebird, blackbirds, and gophers were the leading objects of these studies.

Knowledge of American wildlife was then so meager that it was necessary to collect specimens, ascertain ranges of animals, and assemble data on life histories, habits, and abundance of the various species in order to answer the fundamental questions that arose and to provide information basic to the work of the organization itself. When agricultural and livestock interests required Federal help in controlling rodents and predators, the subject was assigned to this agency. Taken up on the National Forests in 1907, this work was greatly expanded from 1915 on, becoming one of the major phases of operation.

Studies of birds demonstrated their usefulness and surveys revealed the serious depletion of valuable wildlife; thus the need for conservation became urgently apparent. The Biological Survey, an agency of wildlife specialists and conservationists, became its advocate. When international treaties, first with Great Britain acting for Canada, and later with Mexico, made migratory bird protection a Federal obligation, the administrative and regulatory work was assigned to this agency.

Thus developed by the logic of history, from a unit at first concerned only with the agricultural relations of birds, the Biological Survey, which for many years not only served the agricultural needs that involved wildlife but also turned to the advantage of wildlife its associations with the land-utilization programs of the Department of Agriculture.

During its first two decades this agency was primarily engaged in scientific research, a line that was continued throughout the Bureau's history and was regarded at all times as fundamental.

Considering the results of laboratory studies and field observations, the investigators made recommendations as to the protection of useful, and the control of injurious, species.

A comprehensive report on the first species exhaustively studied came in 1889 with the publication of Walter B. Barrow's Biological Survey Bulletin 1, "The English Sparrow (Passer domesticus) in North America, Especially in Its Relations to Agriculture," a work described at that time as "the most important treatise ever published upon the economic relations of any bird."

It is interesting to note here that the last technical report of the Bureau of Biological Survey issued by the Department of Agriculture also dealt with the English sparrow. It was Technical Bulletin 711 entitled "Economic Status of the English Sparrow in the United States" by E. R. Kalmbach. It was based on examination of a larger number (some 8,000) of stomach contents than have been analyzed for a report on any other species of bird.

Four years after the appearance of Bulletin 1 came the publication, in 1893, of A. K. Fisher's classic work on The Hawks and Owls of the United States in Their Relation to Agriculture. This 210-page book, with 26 colored plates, pointed out that contrary to popular notion most of the hawks are either beneficial or neutral. It substantiated its conclusions with scientific data and thus demonstrated in an effective way the importance of basing attitudes toward wildlife on carefully determined facts. In the same year the first similar report on mammals appeared in Vernon Bailey's

Biological Survey Bulletin 4, "The Prairie Ground Squirrels, or Spermophiles, of the Mississippi Valley."

Through the course of years a staff of food-habit analysts, dean of whom was F. E. L. Beal, reported upon group after group of birds. Their publications guided public thought on bird protection, and resulted in the eventual adoption by every State of the American Ornithologists' Union model law, or equivalent legislation, for the protection of birds. Such laws in conjunction with the migratory-bird treaty acts give the United States the best code of bird protection in the world.

Bird Migration

With the data on bird migration received from the American Ornithologists' Union and continuing reports from the Union's members and other observers in all parts of the country, it was possible by 1888 to publish a Report on Bird Migration in the Mississippi Valley in the Years 1884 and 1885, that was prepared by Wells W. Cooke. Largely through his devoted efforts, unparalleled masses of data on bird migration and distribution were accumulated.

Professor Cooke, who became known as the father of bird-migration studies in America, published six monographs on the range and movements of birds of as many families, and in 1915 the Bureau issued his general treatise on Bird Migration, which was later revised and enlarged in a technical bulletin on The Migration of North American Birds, by Frederick C. Lincoln.

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Information on the geographic distribution of birds continued to be accumulated, classified, and used in the preparation of distribution maps and in contributions to many notable publications, among them the series on Life Histories of North American Birds, by A. C. Bent, published by the Smithsonian Institution, and the American Ornithologists' Union's Check-Lists of North American Birds.

Closely related observations on the numbers of birds were also kept on record from the early years of the Bureau's work. In 1916, Cooke published a Preliminary Census of Birds of the United States, a line of work continued for the Bureau by his daughter, May T. Cooke, and others. While "censuses" in the meaning of actual counts of birds have been abandoned as impracticable, the "inventories" of waterfowl, organized annually since 1935 by Mr. Lincoln, have been highly successful in indicating the population trends of this group.

Bird Banding

The work of the American Bird Banding Association was taken over by the Bureau of Biological Survey in 1920 and since that time it has accumulated, by the banding method, data that have been invaluable in connection with all studies of the migration, distribution, and abundance of birds, and in connection with the formulation annually of regulations for the taking of migratory waterfowl.

As correct identification of each form of wildlife is essential in administering this resource, an objective of the organization has been to assure that possibility. Called upon by other governmental agencies,

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various institutions, and the public, for the identification of many animals, the early workers collected specimens from all sections of the country on a scale never before attempted,and studied, described, and named them, in many instances finding that they were forms new to science.

Naming The Animals

It has been said of C. Hart Merriam that he named more animals than Adam did. Many species and subspecies were first described by workers of the Biological Survey, and many of them carry names honoring the describers' colleagues in the Bureau. Among these taxonomists were Dr. Merriam, Vernon Bailey, W. H. Osgood, E. W. Nelson, E. A. Goldman, H. H. T. Jackson, A. H. Howell, and Harry C. Oberholser.

Systematic collection of specimens and related data from the first involved extensive work by field naturalists. In organizing and orienting the early field work, Dr. Merriam was much influenced by the concept of life zones that had been advanced by Humboldt and others. This was essentially an ecological concept, in accordance with which natural life zones were mapped from data on the distribution of both plant and animal life as determined basically by temperature, influenced by altitude, latitude, and exposure, modified by humidity, and other factors, and noted mainly during the breeding, growing, and fruiting seasons.

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The Biological Surveys

Gathering of such data proceeded, along with specimen collection and other field work of the agency, and work began on the production of colored life-zone maps of the entire continent. By 1890 this undertaking had become so central in all of the agency's work that the Department of Agriculture's annual report declared that the Division "is in effect a biological survey, and should be so named, for its principal occupation is the preparation of large scale maps of North America, showing the boundaries of the different faunas and floras, or life areas."

An agricultural as well as biological importance was attributed to this work. In 1897, the year after the proposed change in name was made, the Department of Agriculture's Yearbook declared that: "The colored maps prepared by the Biological Survey furnish the first rational basis the American farmer and fruit grower has ever had for the intelligent distribution of seeds and the only reliable guide he can find in ascertaining beforehand what crops and fruits are likely to prove successful on his own farm, wherever it may be located." It is generally recognized today, however, that the biological surveys then begun and since continued are of greatest value for the basic information on wildlife thus assembled.

The surveys were at first carried on through intensive investigations by expeditions of naturalists in areas of critical importance. In 1889 such an expedition to San Francisco Mountain in Arizona and the area of the Little Colorado Desert gathered material that led to the recognition

of seven life zones and the publication of a provisional map. This survey was followed by the Death Valley Expedition of 1891 and later by intensive investigations of other regions, including Mount Shasta in California, the Yukon River Region of Alaska, and other areas in Canada and Mexico, as well as in the United States.

Results of the work were published in the Bureau's series of North American Faunas, many of which were of general as well as biological importance. Edward A Preble's 574-page volume, A Biological Investigation of the Athabaska-Mackenzie Region (1908), for example, made valuable contributions to the geography of the region, which were later recognized by the Canadian Government in naming for Preble an island in Great Slave Lake and a bay of Great Bear Lake.

The North American Fauna series, included not only numerous "biological surveys" as exemplified by Preble's report, but much of the results of the taxonomic investigations previously mentioned, and a few special reports. One of the largest and best of the systematic monographs was W. H. Osgood's Revision of the Mice of the American Genus Peromyscus (285 pp., 1909). A bibliographical work, never surpassed in its field, was T. S. Palmer's Index Generum Mammalium: A List of the Genera and Families of Mammals (984 pp., 1904). The Faunas, continued throughout the connection of the Biological Survey with the Department, comprised more than 50 numbers and formed a set of scientific monographs, rarely if ever equaled, that brought world recognition to the authors and the institutions producing them.

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In the pioneering work of the Biological Survey, the Bureau's scientists not only made fundamental investigations, but also devised many of the techniques that improved their work and that were later widely adopted by other scientists. Regarding the work of Vernon Bailey who was so long Chief Field Naturalist of the organization, it has been pointed out that many of the country's small mammals, including those important to farmers, were unknown to "even the ablest naturalists" until Vernon Bailey devised practicable traps and trapping methods for catching mammals and showed others how these animals might be taken. Bailey was a proponent of humane trapping and invented traps that would catch and hold mammals without injuring them.

Control of Harmful Species

An outstanding result of the Biological Survey's scientific work was the creation of an American wildlife literature in the technical and popular series of the Department of Agriculture. Almost as obvious were the practical applications of this knowledge in two apparently conflicting fields, control and conservation. For few forms of wildlife are either wholly good or entirely bad in relation to man's interests.

The Survey helped people to discriminate between the preponderantly harmful, and the chiefly beneficial, groups and in counseling or aiding in appropriate treatment. The control of injurious forms was a subject of study from the beginning, and the results conveyed to those who needed them, through publications, extension, and cooperation, largely shaped that phase of wildlife management in the United States. From small beginnings, control activities

were greatly expanded following the appropriation in 1915 of $125,000 for predatory animal control in the national forests and on public domain to protect livestock.

Later, through cooperation with the States, the work was increased, and was extended in organized fashion to the control of destructive birds in 1930. In this field the scientists' studies not only made the control activities more efficient, but also served to restrict them to species and even individuals that were actually doing damage. Time and again scientific investigations yielded findings contrary to popular assumptions regarding good or harm done by wild birds and mammals.

Protection of Desirable Species

The other field of scientific findings, was protecting and promoting the welfare of desirable wildlife. Demonstrating the usefulness of many forms, by arousing popular favor, in itself laid the foundation for improved conservation. Discovering and recommending methods for improving the habitat of game birds, waterfowl, and songbirds, were features of the Biological Survey's program for many years. When the country was aroused to earnest efforts in conservation, these activities were the more effective as they were based on scientific findings.

Regulations to restrict the take by hunters, for example, were greatly improved when they were founded upon proved needs of the forms of wildlife concerned instead of upon the consensus of those with political and often narrow sporting interests. The establishment of refuges was the more

successful because the areas were chosen after biological investigations as to their suitability and because they were developed in the light of scientific knowledge of the food habits and other characteristics of the wildlife they were designed to protect.

Finally the Biological Survey, thoroughly equipped with knowledge of wildlife and with practical experience in administering it, became the Federal Government's instrument for the extensive wildlife restoration program, which with renewed impetus in the 1930's became a great movement for the conservation of a natural resource--a movement that was essentially a part of the Department of Agriculture's land-utilization program.

Food and Drug Administration

The work now carried on by the Food and Drug Administration rather naturally originated in the Department of Agriculture since this Department concerned itself so largely with the American food supply. Food adulterations and fraudulent fertilizers began to engage the attention of its workers early in its history.

The Commissioner of Patents, on the basis of an appropriation of $1,000 made by Congress in 1848, engaged Lewis C. Beck, from the faculty of Rutgers College to conduct an investigation on the breadstuffs of the United States. Beck's report was published in the Patent Office's report on agriculture for 1848. Pages 49-82 of the Report for 1849 also call attention to the adulteration of flour with alum, potato starch, and other substances.

The Report of the Commissioner of Agriculture for 1880 carried a paragraph explaining why the Department could not then prohibit food adulterations. This paragraph was printed because frequent inquiries came in asking whether the Department could not undertake this function. There was constant agitation then for passage of a stringent law making it a crime to manufacture spurious articles or to adulterate genuine ones. At that time the Government already regulated imported articles, especially drugs. Publication of this paragraph indicates an interesting trend in public opinion more than 25 years before the first Food and Drug Law was passed in 1906.

When the act was passed the Department's Bureau of Chemistry was

charged with its enforcement. This regulatory work was placed in a separate unit, first named the Food, Drug, and Insecticide Administration in 1927. The new unit also absorbed the work of the Insecticide and Fungicide Board which had been set up in 1911 to enforce the Insecticide Act. It became the Food and Drug Administration in 1930, and was transferred to the Federal Security Agency June 30, 1940, pursuant to Reorganization Plan No. IV.

Research carried on by scientists in this Administration almost entirely concerned itself with methods of chemical, biochemical, microanalytical, physical, and bacteriological analysis. This work aided in the detection of fraud and of adulterations. It therefore had definite and considerable monetary value to consumers, though it is practically impossible to estimate this in dollar terms. It likewise aided producers by weeding out unfair competition.

About 1873 the Department chemist, William McMurtrie, was asked to devote his time to the examination of strictly agricultural products. This was because Commissioner of Agriculture Watts had been annoyed by private individuals who wanted the chemist to test wines, patent medicines, and ore samples for them. As there were loud complaints about fraud in the commercial fertilizer field, the chemist analyzed a number of fertilizers and published the results.

charged with its enforcement. This regulatory work was placed in a separate unit, first named the Food, Drug, and Insecticide Administration in 1927. The new unit also absorbed the work of the Insecticide and Fungicide Board which had been set up in 1911 to enforce the Insecticide Act. It became the Food and Drug Administration in 1930, and was transferred to the Federal Security Agency June 30, 1940, pursuant to Reorganization Plan No. IV.

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Harvey W. Wiley

About 1878, under Commissioner Le Duc, the Department chemist was requested by the city government of the District of Columbia to analyze cream puffs and coffee suspected of having been poisoned, as well as supposedly adulterated bologna sausage and tea. The chemist furthermore examined certain coffee and tea substitutes, some baking powders, butters, and oleomargarines, and a tonic called "Boneset." In publishing the analysis of the last-named the chemist made clear that it was a misrepresented article.

In 1883, Harvey W. Wiley became the Department chemist and soon thereafter reported on the adulterants of butter, tea, coffee, and cocoa, and on meat preservatives. The Department microscopist, Thomas Taylor, had earlier done noteworthy work on the adulteration of butter and of fats and oils generally. Wiley continued his studies of foods and food adulterants, publishing the results. He thus built the groundwork for passage of the Food and Drug Act of 1906. By 1900 his publications had far-reaching influence.

Wiley had to develop his methods of analysis as he went along. As methods of food processing changed, and food-adulteration techniques became more subtle and refined there was constant necessity for further research on and refinement of methods. Students met the Wiley bulletins early in their college studies.

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Adulterants. It was published in ten parts, the first of which appeared in 1887 and the last in 1902. Later publications of basic importance were Bulletin 65, Provisional Methods for Analysis of Foods Adopted by the Association of Official Agricultural Chemists, issued in 1902, and Bulletin 107, the Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists, issued in 1907.

Dr. Wiley is still dimly remembered by some as the man who had the "poison squad." This was started in the fall of 1902, four years before the Food and Drug Law was passed. To study the effect of certain commonly used food preservatives on health, Wiley ran experiments on human subjects, mostly fellow employees, who had their meals at a table in the Bureau of Chemistry. Whatever opinion scientists ultimately formed regarding the validity of some of the conclusions reached by Wiley, the work at least definitely stimulated further research.

Foods

Later, the Remsen Referee Board worked on the physiological effects of benzoate of soda, sulfur dioxide, and saccharin, when used in the ordinary way in foods. Investigational techniques were ultimately developed which proved of considerable value. In any case Wiley had the faculty of attracting public attention regardless of what he undertook, a gift shared by few genuine scientists. Passage of the original Food and Drug Act came largely from his personal agitation.

So rapid was progress in the field of food preservation and processing, that even in 1907 the analytical methods available to the chemist for examining foods and drugs were few and inexact. Today, as a result of the labor of a generation of Federal scientists and innumerable collaborators, one of the finest collections of analytical methods extant has been developed.

Only some of the more notable work can be mentioned. The Food Research Division in Wiley's time was located in Philadelphia and was directed by Mary E. Pennington. Dr. Pennington did pioneer work on problems concerned with the preparation, processing, and storing of foods, especially poultry and fish. These studies were undertaken primarily to educate the food industries on the use of such processing and storing methods as would enable them to meet the requirements of the new Food and Drug Act.

This is an early example of the constructive type of work that has engaged the food and drug officials. Not only have its scientists developed methods for the detection of frauds and adulterants, but they have undertaken research investigations designed to enable manufacturers to meet the increasingly stringent requirements of laws regulating the food, drug, and cosmetic industries. This educational technique was bitterly criticized by Wiley in the later years of his life, though he himself initiated it.

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The work of the Association of Official Agricultural Chemists also early resulted in the development of highly accurate and specialized

methods for the analysis of fertilizers, foods, drugs, and related products. Men like R. E. Doolittle, and A. F. Seeker made contributions that should be mentioned. The sugar investigations carried on by C. A. Browne and his coworkers, the microscopical work of Andrew L. Winton, and W. D. Bigelow's work on food products were all outgrowths of regulatory requirements. They had definite, basic scientific value.

As has been indicated, such work has had to be continuous. Over and over again new methods of food processing, preservation, handling, or storing, as well as subtler and more refined techniques of fraud and adulteration have compelled chemists in the Food and Drug Administration to develop new methods of analysis or detection before legal action could be taken. This has required exacting research and no little ingenuity.

Outstanding is the work of the Food Division in the development of quick and accurate analytical methods for the determination of traces of lead, arsenic, and fluorine left on fruits and vegetables as spray residues. Its workers have also developed refined methods of extraordinary precision for the quantitative determination of fruit acids which methods have had decisive diagnostic value in the examination of fruit products to determine compliance with the law.

Work has been done on methods for the estimation of volatile acids as a measure of the partial decomposition of food products. Scientists in the Food Division have also developed methods for the objective measurement of quality factors in canned fruits and vegetables.

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Novel methods of far-reaching application were also developed for the identification of various genuine and imitation fruit flavors. The application of these methods has checked many abuses in the way of substituting highly concentrated imitation flavors for genuine fruit ingredients in food products. The economic significance of this work to fruit growers has been large.

Microscopy

In 1871 the Division of Microscopy was established in the Department of Agriculture with Thomas Taylor in charge. He not only investigated cranberry rot, mushroom culture, grape mildew, peach yellows, and black knot of plums, in every case benefiting growers financially, but he also devised a microscopic method of detecting adulterants in butter. Microscopic work has been of great aid in food and drug work.

In recent years this has been carried on under the direction of Burton J. Howard. The Howard mold-count method is not only the standard regulatory means of determining the presence of decomposed tissues in tomato products, but it is also used by processing plants as a factory-control method to ensure the production of sound products.

Later John D. Wildman developed a mold-count method for the detection of butter made from moldy and decomposed cream. Again a control procedure was devised which materially improved the general quality of an important food product. Extensive research has been carried on upon methods for the determination of decomposition factors in cream and butter generally also in cooperation with the microanalysts.

Many methods have been developed for the detection and identification of filth present in food. These are based upon the oil-flotation technique and are particularly valuable as the presence of such matter in minute particles would otherwise go undetected.

In 1924 whole counties of blueberry growers were threatened with ruin because of the presence of the blueberry maggot in their products. Microscopic methods of detection were developed by Howard and his coworkers. They also went further; to save the growers they devised a mechanical device that proved to be the salvation of the Maine blueberry canning industry. It separated the sound from the maggoty, wormy, or otherwise unfit berries. A public-service patent was procured; the device made available to and was largely adopted by the packers who thereafter had no trouble with the law on this score.

Drugs

At the Seventy-Eighth Meeting of the American Pharmaceutical Association, May 5-10, 1930, the Ebert Medal was presented to Marvin R. Thompson, an assistant pharmacologist of the Food and Drug Administration, for his basic research on ergot. Thompson's study stimulated further work on the biological assay of ergot preparations and accelerated the search for biologically active substances in ergot which were not identical with known simple amino compounds and ergot alkaloids.

Some years later the Ebert Medal was awarded to Lloyd C. Miller, also of the Pharmacological Division, for his work on the assay of digitalis. Considerable work of outstanding value was done by

Herbert O. Calvery and associates on the chronic toxicity of lead and arsenic.

Another outstanding piece of work is the study made of the toxicology of certain glycols and their derivatives. The results of this work will aid in forestalling another such tragedy as that which occurred in 1938 when about a hundred people were killed by innocently using a sulfanilamide preparation containing poisonous diethylene glycol.

Vitamins

The Vitamin Division under E. M. Nelson has had likewise to develop new assay methods in its field. One notable development has been an improved assay method for vitamin B_1. Another concerns a cooperative investigation carried on with the Children's Bureau of the Department of Labor on the relative antirachitic value of cod-liver oil and viosterol.

The Bacteriological Division recently perfected a method for determining the effect of chemical antisepsis on phagocytosis; it promises to have wide application. The initial publication which appeared in 1940 has been followed by several others.

Social Value of This Work

In general, the scientific work carried on by the staff of this agency has had broad social, industrial, and economic values. It did much to prevent unfair competition in trade, as well as to protect consumers from physical or economic injury by misbranded, adulterated, or deleterious food and drug products. It aided the agricultural industry in producing

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SECTION XIII

THE PUBLICATION OF RESEARCH

The act creating the Department of Agriculture stated that the "general designs and duties" of the Department "shall be to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word." Obviously, the Department was established not only to make investigations and acquire information, but in some manner to acquaint the public who paid for its activities with their nature and accomplishments.

Soon after 1836 the annual reports of the Commissioner of Patents began to contain material of interest to agriculturalists. In time, this grew to the extent that a man especially qualified in agriculture was employed to edit and, in part, to write what eventually became an annual book on purely agricultural matters. This book contained articles by outside writers, reports, and replies to correspondence. Initially the annual publications of the Department of Agriculture followed the same pattern.

The Department also issued scientific and technical reports. This sort of thing really began when the Congress in 1828 authorized the printing as a document of Count Von Hazzi's <u>A Treatise on the Rearing of Silkworms</u>. Two years earlier the House had ordered published the 220-page

document on silk, produced by Secretary of the Treasury Rush in response to its resolution of May 11, 1826. The first publication issued by the Department in 1862 was a pamphlet on The Present Agricultural, Mineral, and Manufacturing Conditions and Resources of the United States by the first head of the Department Commissioner of Agriculture, Isaac Newton.

In 1862 there was also issued a research publication by the Department's first chemist, Charles M. Wetherill. It was a Report on the Chemical Analysis of Grapes. Other such publications followed, becoming more technical and specialized as science itself progressed and proliferated. By the time the head of the Department assumed Cabinet rank it was realized that its publication policy required more attention.

The necessity for increased publication of agricultural information in popular form was realized to be urgent by Secretary of Agriculture, Jeremiah M. Rusk, who assumed office in 1889. In addition to the rather popular annual agriculture book, containing as it now did reports from those in charge of various lines of investigation, the Department had tried publishing monthly reports. But even this did not supply the need for getting popularly expressed technical information to those in need of it quickly enough to do the most good.

As W. O. Atwater had also seen this difficulty he proposed that a series of Farmers' Bulletins be instituted to solve it. This was done. George William Hill was appointed to supervise editing and publishing, and the issuance of popular publications was begun. Rusk's successor, J. Sterling Morton, established a Division of Publications. Thereafter

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there was a gradual evolution to the point where specialized editors were employed to bring Department publications to approved standards.

For a long time, however, the technical publications continued to be issued not only by the Bureaus but by the Sections and Divisions that in some cases later became Bureaus. The complexity of this publication policy ultimately became so great that it proved too confusing to be continued. In 1913 the Bureau series of publications was largely consolidated into the Department series. In 1926 the Division of Publications became part of the newly created Office of Information.

During the first 79 years of its life the Department issued 253 series of publications, including 43 periodicals, all of which are now defunct. The total number of separate publications--not copies--in the numbered series was 10,516. These were issued from 66 bureaus or administrative units of one sort or another, many of which have since been reorganized, transferred, or abolished.

At the outbreak of the second World War the Department was issuing 98 series of publications, including 16 periodicals. These were exclusive of the publications prepared by Bureaus which were transferred to other Government agencies from 1939 on.

Today the Farmers' Bulletins and Leaflets, with folders of various kinds, contain popularized scientific information. But most of the research and technical material which is published as such now appears in the Journal of Agricultural Research, and in such series as Technical Bulletins, Circulars, Miscellaneous Publications, Statistical Bulletins, Soil Surveys, the Hydrologic Bulletins, and the Land Use and Erosion Surveys.

Although the passage of time had brought numerous changes in the administrative phases of the Department's publication program, the form and structure of its technical and scientific publications have remained fairly well stabilized for a number of years. Their content, however, has undergone extensive modification.

First published in an era when professors of agriculture were just taking their place on college faculties and were recognized authorities in a very broad field, the early agricultural bulletins bore evidence of this in their tendency to generalization and relative linguistic simplicity, although scientific work of great value was performed and its results disseminated in those early days. In time, as science progressed and specialized, and each specialty developed its own technical nomenclature, the content of these publications changed. The number of professionally interested readers naturally becomes smaller as the specialty itself narrows.

The Department's Technical Bulletins contain reports of the more comprehensive types of investigation. Each publication is a separate and independent entity, with a more or less complete statement of the study and the findings on the subject considered. Though these bulletins are in a numbered series, they may differ entirely in subject matter from one to another. Department Circulars and Miscellaneous Publications are semitechnical in character, some leaning towards the popular and others toward the technical.

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The editions of Technical Bulletins and Circulars for free distribution by the Department normally range from 2,500 to 3,500 copies. To these are added the necessary copies for the depository libraries, and a sale stock. In the fiscal year 1941-42, there were distributed free 593,865 copies of Technical Bulletins and Circulars, while the Superintendent of Public Documents sold 53,448 copies.

The Journal of Agricultural Research is a leader in its field. Two thousand copies are issued for free distribution, but in the fiscal year 1940-41, 672 subscriptions to the journal were sold, as well as 18,825 copies of reprints or separates of articles that appeared therein. In addition, the bureau or station of origin is given 250 reprints of each article published. This journal was originally started through the influence of Karl F. Kellerman, who had concluded that neither scientific reviewing journals nor libraries gave to bulletins the attention they accorded to material published in indexed journals.

A long-time historical trend is involved in the issuance of Department publications. For many years a large part of our public has looked to the Department of Agriculture for accurate and unbiased scientific information on a wide variety of subjects. This is traditional. Late in 1889 Secretary Rusk wrote that the Department had received nearly 40,000 letters of inquiry for information between January 1 and October 1 that year. These letters, he said, came "from all sections of the country, from all classes and conditions."

As Secretary Rusk held, it is ill-advised for a Government agency to keep secret the knowledge it gathers or creates. He wrote that,

"Time and expense, ability and experience, lavished on the work of this Department can have no practical results unless we can lay their conclusions promptly before the people who need them." In recent years, of course, all modern forms of communication have been invoked to aid this process, including the press, exhibits, the radio, and the motion picture.

Some of the more popular Department publications have been issued in huge quantities, mounting to two or three millions. In the fiscal year 1941-42, Members of Congress themselves distributed nearly 5,000,000 _Farmers' Bulletins_ and _Leaflets_, and almost 400,000 publications in other series. They also requested 6,874,250 copies of Department lists of _Farmers' Bulletins_ and _Leaflets_ to send to their constituents. Meanwhile, the Department's Office of Information received over 900,000 requests for information or publications, of which 279,000 emanated from offices of Members of Congress.

In that fiscal year about $225,000 was expended for the publication of scientific and technical material and about $406,000 for the publication of popular material. The printing of forms, certificates, instruction pamphlets, reports, periodicals, and other administrative material required, if the planning and regulatory functions of the Department, pursuant to acts of Congress, are to be properly carried out, absorbs the bulk of the printing funds. In the fiscal year mentioned, the sum required for this purpose was $1,155,000.

Because of the continuous pressure on its printing funds, it has not been possible for the Department to publish all the technical and

research material written by its staff of specialists. During the fiscal year 1941-42, a total of 1,974 articles or addresses, mostly technical, were issued through outside journals. To provide for the further distribution of 265 of these, about 200 reprints of each were purchased. On the other hand, there were sent to the Governing Printing Office during that fiscal year only 237 technical and scientific manuscripts, or 12 percent as many, for issuance as Technical Bulletins, Circulars, Miscellaneous Publications, Statistical Bulletins, Soil Surveys, and articles in the Journal of Agricultural Research.

The Department of Agriculture is a research and an educational institution as well as a planning and regulatory agency. It is continually creating scientific knowledge. To give this knowledge power, it must be published.

SECTION XIV

REFERENCE LIST OF THOSE IN CHARGE OF THE SCIENTIFIC AGENCIES

For purposes of reference the following list of the individuals who have headed the various scientific agencies is appended. The dates are not exact in all cases. In some instances the head of the division, section, or office is given before the work administratively assumed bureau status, but the dates when the bureaus were founded are all given in the discussions regarding scientific work therein. Possibly some of the names or dates are incorrect, but this is the best that the Office of Personnel, to which many thanks, could do at present.

Bureau of Animal Industry

Salmon, D. E. (May 31, 1884 - October 31, 1905)
Melvin, A. D. (December 1, 1905 - December 7, 1917)
Mohler, John R. (December 11, 1917 - July 31, 1943)
Miller, Arthur W. (August 1, 1943 - present.)

Office of Experiment Stations

Atwater, Wilbur O. (October 1888 - August 1891)
Harris, Abram W. (August 1891 - September 1893)
True, Alfred C. (September 1893 - June 1915)
Allen, Edwin W. (July 1, 1915 - November 11, 1929)
Evans, Walter H. (November 1929 - September 1931)
Jardine, James T. (September 1931 - present)

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Allen, Edwin W. (July 1, 1915 - November 11, 1929)
Evans, Walter H. (November 1929 - September 1931)
Jardine, James T. (September 1931 - present)

Weather Bureau

Harrington, Mark W. (July 1, 1891 - June 30, 1895)
Moore, Willis L. (July 1, 1895 - April 16, 1913)
Williams, Henry E. (April 17, 1913 - August 3, 1913) (acting)
Marvin, Charles F. (August 4, 1913 - January 30, 1934)
Gregg, Willis R. (January 31, 1934 - September 14, 1938)
Clark, Charles C. (September 15, 1938 - December 14, 1938) (acting)
Reichelderfer, Francis W. (December 15, 1938 - January 1, 1939) (acting)
Reichelderfer, Francis W. (January 2, 1939 - present)

Bureau of Plant Industry

Galloway, B. T. (July 1, 1901 - March 16, 1913)
Taylor, W. A. (March 17, 1913 - December 31, 1933)
Ryerson, K. A. (January 1934 - October 22, 1934)
Richey, F. D. (November 7, 1934 - March 10, 1938)
Auchter, E. C. (March 11, 1938 - April 8, 1942) (Became Administrator of Agricultural Research)
Salter, R. M. (April 9, 1942 - present)

Bureau of Public Roads

Stone, G. R. (October 3, 1893 - June 1898)
Dodge, Martin (June 1898 - January 1899)
Stone, G. R. (January 1899 - October 1899)
Dodge, Martin (October 1899 - 1904)
Page, Logan W. (1905 - December 9, 1918)
MacDonald, Thomas H. (May 1919 - present)

Bureau of Forestry and Forest Service

Hough, F. B. (1876 - 1883)
Egleston, N. H. (1883 - 1886)
Fernow, B. E.(1886 - 1898)
Pinchot, Gifford (1898 - March 3, 1905)
Pinchot, Gifford (March 3, 1905 - February 1910) (Forest Service)
Graves, Henry S. (February 1910 - April 1920)
Greenly, W. B. (April 1920 - April 1928)
Stuart, Robert Y. (May 1928 - October 1933)
Silcox, Ferdinand A. (November 1933 - January 1939)
Clapp, Earle H. (January 1939 - January 7, 1942) (acting)
Watts, Lyle F. (January 8, 1942 - present)

Bureau of Home Economics

Stanley, Dr. Louise (1923 - present)

Bureau of Human Nutrition and Home Economics

Sherman, Henry C. (1943 - present)

Biological Survey

Merriam, C. Hart (1905 - 1910)
Henshaw, H. W. (1910 - 1916)
Nelson, E. W. (1916 - May 1927)
Reddington, Paul G. (May 1927 - March 1934)
Darling, J. N. (March 1934 - November 15, 1935)
Gabrielson, Ira N. (November 16, 1935 - present)

Bureau of Dairying and of Dairy Industry

Larson, C. W. (July 1924 - 1926)
Larson, C. W. (1926 - January 1, 1928) (Dairy Industry)
Rogers, L. A. (January 1928 - September 1928) (acting)
Reed, O. E. (September 1928 - present)

Food and Drug Administration

Campbell, Walter G. (July 1, 1927 - present)

Bureau of Home Economics

Stanley, Dr. Louise (1923 - present)

Bureau of Human Nutrition and Home Economics

Sherman, Henry C. (1943 - present)

Biological Survey

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Redington, Paul G. (May 1927 - March 1934)
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Food and Drug Administration

Campbell, Walter G. (July 1, 1927 - present)

Bureau of Agricultural and Industrial Chemistry

Skinner, W. W. (February 23, 1943 - present)

Bureau of Agricultural Chemistry and Engineering

Knight, H. G. (October 1938 - July 13, 1942)
Skinner, W. W. (July 14, 1942 - November 24, 1942) (acting)
Skinner, W. W. (November 24, 1942 - February 21, 1943)

Bureau of Agricultural Engineering

McCrory, S. H. (July 1, 1931 - October 1938)

Bureau of Chemistry

Wiley, H. W. (1901 - February 1912)
Doolittle, R. E. (February 1912 - December 1912)(acting)
Alsberg, C. L. (December 1912 - 1921)
Campbell, W. G. (1922 - 1923) (acting)
Browne, C. A. (1923 - 1927)

Bureau of Entomology and Plant Quarantine

Strong, Lee A. (July 1, 1934 - June 2, 1941)
Hoyt, Avery S. (June 2, 1941 - June 30, 1941) (acting)
Annand, P. N. (July 1, 1941 - present)

Bureau of Entomology

Glover, Townend (1862 - 1878)
Riley, Charles V. (1878 - April 1879)
Comstock, John H. (May 1879 - March 1881)
Riley, Charles V. (March 1881 - June 1894)
Howard, L. O. (July 1, 1904 - October 15, 1927)
Marlatt, C. L. (October 15, 1927 - July 1, 1934)

Bureau of Chemistry and Soils

Knight, H. G. (July 1, 1937 - October 1938)

Bureau of Soils

Whitney, Milton (1901 - 1926)
McCall, A. G. (January 1927 - July 1927)

Soil Conservation Service

Bennett, H. H. (April 27, 1935 - present)

Bureau of Plant Quarantine

Strong, Lee A. (October 15, 1927 - July 1, 1934)

Plant Quarantine and Control Administration

Strong, Lee A. (1927 - 1929)

Federal Horticulture Board

Marlatt, Charles L. (June 29, 1912 - October 15, 1927)

Stauffer